The Meaning of “Higgs”:
$\tau\tau$ and $\gamma\gamma$ at Hadron Colliders

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Based on:
A. Belyaev, A. Blum, S. Chivukula, E. Simmons; hep-ph/0506086
Introduction

Supersymmetry (MSSM)

Dynamical Symmetry Breaking (Technicolor)

Distinguishing MSSM from Technicolor

Conclusions
As you are all well aware...

The origin of electroweak symmetry breaking remains unknown.

CDF and D0 are searching hard for signs of either
a Standard Model (SM) Higgs boson
or Beyond the Standard Model (BSM) physics such as
Supersymmetry or Dynamical Symmetry Breaking

The production cross-sections and decay branching fractions of the SM Higgs have been predicted in great detail. Search strategies have been optimized and re-optimized.
What happens if the Tevatron finds evidence for a new scalar state?
The Meaning of “Higgs”

- What happens if the Tevatron finds evidence for a new scalar state?

- How sure will we be that it is really the SM Higgs?
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- How sure will we be that it is really the SM Higgs?

- The spectra of many BSM scenarios include (pseudo) scalar states whose masses can lie in the range to which Tevatron Run II is sensitive.

- This talk looks at the possibility of extracting information about BSM physics from the searches for a light SM Higgs now underway at Run II and planned for the LHC.
The literature* includes many papers that use LEP’s SM Higgs search results to constrain BSM physics. The Tevatron and LHC are sensitive to heavier scalars than LEP, so the strategy bears repeating.

The literature* on hadron collider Higgs searches identifies the $\tau\tau$ channel as potentially valuable for enhancing the visibility of an SM Higgs or rendering an MSSM Higgs visible via $gg \rightarrow h_{MSSM} \rightarrow \tau\tau$.

We build on this in three ways
- additional production mechanism ($b\bar{b} \rightarrow h$)
- additional decay channels ($h \rightarrow b\bar{b}, W^+W^-, ZZ, \gamma\gamma$)
- comparing Supersymmetry with Dynamical Symmetry Breaking

* See references 1-12 of hep-ph/0506086.
In the presence of BSM physics, such as SUSY or Dynamical Symmetry Breaking, the SM Higgs gives way to the multiple Higgs bosons of the MSSM or the technipions of technicolor.

We will look at the extent to which the signal in certain standard Higgs search channels is enhanced when one is seeing a BSM scalar ($\mathcal{H}$) rather than an SM Higgs.

We define the enhancement factor for the process $yy \rightarrow \mathcal{H} \rightarrow xx$ as

$$\kappa_{yy/xx}^{\mathcal{H}} = \frac{\Gamma(\mathcal{H} \rightarrow yy) \times BR(\mathcal{H} \rightarrow xx)}{\Gamma(h_{SM} \rightarrow yy) \times BR(h_{SM} \rightarrow xx)}$$
Supersymmetry (MSSM)

- Each ordinary fermion (boson) is paired with a new boson (fermion).
- Two Higgs doublets exist to provide masses to both up-type and down-type quarks, and to ensure triangle anomaly cancellation.
  \[ \Phi_d = (\Phi^0_d, \Phi^-_d) \text{ and } \Phi_u = (\Phi^+_u, \Phi^0_u) \]
  \[ \langle \Phi_d \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} v_d \\ 0 \end{pmatrix}, \quad \langle \Phi_u \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v_u \end{pmatrix}, \quad \sqrt{v_d^2 + v_u^2} = 246 \text{ GeV.} \]
- SUSY relates the scalar self-coupling to gauge couplings \( \Rightarrow M_H \) is predicted!
- Of the 8 degrees of freedom in the Higgs sector, 3 serve as “eaten” Goldstone bosons, leaving 5 states in the spectrum:
  - Two neutral, CP-even states: \( h, H \) (mixing \( \alpha \))
  - One neutral, CP-odd state: \( A \)
  - A charged pair: \( H^\pm \)
Yukawa interactions in MSSM

At tree level, the Higgs sector is defined by $\tan \beta = v_u/v_d$ and $M_A$

One derives $h_t = \frac{\sqrt{2} m_t}{v_u} = \frac{\sqrt{2} m_t}{v \sin \beta}$, $h_{b, \tau} = \frac{\sqrt{2} m_{b, \tau}}{v_d} = \frac{\sqrt{2} m_{b, \tau}}{v \cos \beta}$

$Y_{ht\tilde{t}}/Y_{ht\tilde{t}}^{SM} = \cos \alpha / \sin \beta$ \hspace{1cm} $Y_{hb\tilde{b}}/Y_{hb\tilde{b}}^{SM} = - \sin \alpha / \cos \beta$

$Y_{Ht\tilde{t}}/Y_{ht\tilde{t}}^{SM} = \sin \alpha / \sin \beta$ \hspace{1cm} $Y_{Hb\tilde{b}}/Y_{hb\tilde{b}}^{SM} = \cos \alpha / \cos \beta$

$Y_{A\tilde{t}\tilde{t}}/Y_{ht\tilde{t}}^{SM} = \cot \beta$ \hspace{1cm} $Y_{A\tilde{b} \tilde{b}}/Y_{hb\tilde{b}}^{SM} = \tan \beta$

For large $M_A$ \hspace{1cm} $\Rightarrow Y_{Hb\tilde{b}}/Y_{hb\tilde{b}}^{SM} = Y_{H\tau\tilde{\tau}}/Y_{h\tau\tilde{\tau}}^{SM} \simeq \tan \beta$,

For small $M_A \sim M_h$ \hspace{1cm} $\Rightarrow Y_{hb\tilde{b}}/Y_{hb\tilde{b}}^{SM} = Y_{h\tau\tilde{\tau}}/Y_{h\tau\tilde{\tau}}^{SM} \simeq \tan \beta$

At large $\tan \beta$, we see enhancements of the Yukawa couplings $(Y_{A\tilde{b} \tilde{b}}, Y_{A\tau\tilde{\tau}})$ and also of either $(Y_{Hb\tilde{b}}, Y_{H\tau\tilde{\tau}})$ or $(Y_{hb\tilde{b}}, Y_{h\tau\tilde{\tau}})$ depending on the size of $M_A$. 
Neutral Higgs bosons could be degenerate and contribute to the same signal. We assume this happens if $|M_A - M_h|$ and/or $|M_A - M_H|$ is less than $0.3 \sqrt{M_A/\text{GeV}}$ GeV for $\tau\tau$ or $b\bar{b}$ channels.
Jumping ahead slightly... combining signals from degenerate $\mathcal{H}$ makes the enhancement factor essentially independent of the degree of top-squark mixing (for fixed $M_A$ and $\mu$ and moderate-to-high $\tan \beta$)

$$bb \rightarrow A + H + h \rightarrow \tau \tau, \tan \beta = 50, \text{Minimal mixing scenario}$$

$$bb \rightarrow A + H + h \rightarrow \tau \tau, \tan \beta = 50, \text{Maximal mixing scenario}$$
Factors affecting signal strength in comparison with SM - II

- Alterations of the couplings directly affect widths and branching ratios relative to those in the SM. But: a gain in $B(H \rightarrow \tau\tau)$ caused by a smaller $b\bar{b}H$ coupling may be offset by a reduction in Higgs production.
**Factors affecting signal strength in comparison with SM - II**

- Alterations of the couplings directly affect widths and branching ratios relative to those in the SM. **But:** a gain in $B(H \rightarrow \tau \tau)$ caused by a smaller $b\bar{b}H$ coupling may be offset by a reduction in Higgs production.

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**SM Higgs**

![Graph showing BR vs. $M_{h^{sm}}$(GeV)]

**MSSM Axial Higgs, tb=5**

![Graph showing BR vs. $M_A$(GeV)]
Factors affecting signal strength in comparison with SM - II

- Alterations of the couplings directly affect widths and branching ratios relative to those in the SM. But: a gain in $B(\mathcal{H} \rightarrow \tau\tau)$ caused by a smaller $b\bar{b}\mathcal{H}$ coupling may be offset by a reduction in Higgs production.

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**SM Higgs**

![Graph showing BR vs. $M_{h^{\text{sm}}}$ (GeV)]

**MSSM Axial Higgs, $tb=10$**

![Graph showing BR vs. $M_A$ (GeV)]
Factors affecting signal strength in comparison with SM - II

Alterations of the couplings directly affect widths and branching ratios relative to those in the SM. But: a gain in $B(\mathcal{H} \to \tau\tau)$ caused by a smaller $b\bar{b}\mathcal{H}$ coupling may be offset by a reduction in Higgs production.

![Graph of SM Higgs vs. $M_{h^{\text{sm}}}$(GeV)]

![Graph of MSSM Axial Higgs, $tb=50$ vs. $M_{A}$(GeV)]
Factors affecting signal strength in comparison with SM - III

- A larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - Direct $b\bar{b} \rightarrow \mathcal{H}$ production
Factors affecting signal strength in comparison with SM - III

- a larger $b\bar{b}H$ coupling increases both
  - $gg \rightarrow H$ through a $b$-quark loop
  - direct $b\bar{b} \rightarrow H$ production
Factors affecting signal strength in comparison with SM - III

- a larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - direct $b\bar{b} \rightarrow \mathcal{H}$ production

(a) Tevatron, $\sqrt{s} = 1.96$ TeV, SM

(b) Tevatron, $\sqrt{s} = 1.96$ TeV, MSSM, $\tan \beta = 10$
Factors affecting signal strength in comparison with SM - III

- A larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - Direct $b\bar{b} \rightarrow \mathcal{H}$ production
Factors affecting signal strength in comparison with SM - III

- A larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - Direct $b\bar{b} \rightarrow \mathcal{H}$ production

(a) Tevatron, $\sqrt{s} = 1.96$ TeV, SM

(d) Tevatron, $\sqrt{s} = 1.96$ TeV, MSSM, $\tan\beta = 50$
Factors affecting signal strength in comparison with SM - III

- a larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - direct $b\bar{b} \rightarrow \mathcal{H}$ production

(a) LHC, $\sqrt{s} = 14.0$ TeV, SM

(b) LHC, $\sqrt{s} = 14.0$ TeV, MSSM, $\tan\beta = 5$
Factors affecting signal strength in comparison with SM - III

- A larger $b\bar{b}H$ coupling increases both
  - $gg \rightarrow H$ through a $b$-quark loop
  - Direct $b\bar{b} \rightarrow H$ production

(a) LHC, $\sqrt{s} = 14.0$ TeV, SM

(b) LHC, $\sqrt{s} = 14.0$ TeV, MSSM, $\tan\beta = 10$
Factors affecting signal strength in comparison with SM - III

- A larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \rightarrow \mathcal{H}$ through a $b$-quark loop
  - Direct $b\bar{b} \rightarrow \mathcal{H}$ production

(a) LHC, $\sqrt{s} = 14.0$ TeV, SM

\[\sigma (\text{pb}) \]

\[M_{h^0}^{\text{SM}} (\text{GeV}) \]

- $gg+b\bar{b} \rightarrow h_{\text{sm}}$
- $b\bar{b} \rightarrow h_{\text{sm}}$

(c) LHC, $\sqrt{s} = 14.0$ TeV, MSSM, $\tan\beta = 30$

\[\sigma (\text{pb}) \]

\[M_{A} (\text{GeV}) \]

- $gg+b\bar{b} \rightarrow A$
- $b\bar{b} \rightarrow A$
- $gg \rightarrow A$
Factors affecting signal strength in comparison with SM - III

- a larger $b\bar{b}\mathcal{H}$ coupling increases both
  - $gg \to \mathcal{H}$ through a $b$-quark loop
  - direct $b\bar{b} \to \mathcal{H}$ production

(a) LHC, $\sqrt{s} = 14.0$ TeV, SM

(d) LHC, $\sqrt{s} = 14.0$ TeV, MSSM, $\tan\beta = 50$
Total enhancement of various $pp/p\bar{p} \rightarrow H \rightarrow xx$ channels

(a fractional enhancement denotes suppression)
Total enhancement of various $pp/p\bar{p} \rightarrow \mathcal{H} \rightarrow xx$ channels

(a fractional enhancement denotes suppression)

(a) $gg+bb \rightarrow A+H+h$, $\tan\beta=5$, Tevatron/LHC

(b) $gg+bb \rightarrow A+H+h$, $\tan\beta=10$, Tevatron/LHC
Total enhancement of various $pp/p\bar{p} \rightarrow H \rightarrow xx$ channels

(a fractional enhancement denotes suppression)

(c) $gg+b\bar{b} \rightarrow A+H+h, \tan\beta=30$, Tevatron/LHC

(d) $gg+b\bar{b} \rightarrow A+H+h, \tan\beta=50$, Tevatron/LHC
Visibility of MSSM Higgs bosons: $\tau \tau$ channel
Visibility of MSSM Higgs bosons: $\tau\tau$ channel

Predicted Tevatron reach, based on the $h_{SM} \rightarrow \tau^+\tau^-$ studies

by A.B., T.Han, R.Rosenfeld, hep-ph/0204210

$gg+bb \rightarrow A+H+h \rightarrow \tau\tau$, Tevatron, $\sqrt{s} = 1.96$ TeV

$M_A$ (GeV) vs $\tan\beta$
Visibility of MSSM Higgs bosons: $\tau\tau$ channel

Predicted LHC reach, based on the $h_{SM} \rightarrow \tau^+\tau^-$ studies
by D.Cavalli et al, hep-ph/0203056

$gg+bb \rightarrow A+H+h \rightarrow \tau\tau$, LHC, $\sqrt{s} = 14.0$ TeV

$gg+bb \rightarrow A \rightarrow \tau\tau$, LHC, $\sqrt{s} = 14$ TeV
Scalar states involved in EWSB are manifestly composite at scales not much above the electroweak scale $v \sim 250$ GeV.

A new asymptotically free strong gauge interaction, Technicolor, breaks the chiral symmetries of massless fermions.

The resulting condensate $\langle \bar{f}_L f_R \rangle \neq 0$ breaks the EW symmetry.

Three of the Nambu-Goldstone Bosons (technipions) of the chiral symmetry breaking become the longitudinal modes of the $W$ and $Z$.

Additional light neutral pseudo Nambu-Goldstone bosons, "technipions," remain in the spectrum.

We will compare the lightest technipion in each of several technicolor models with SM Higgs.
Technicolor models under study

1) the traditional one-family model with a full family of techniquarks and technileptons (Farhi and Susskind, Nucl. Phys. B 155 (1979) 237.)

2) on the one-family model in which the lightest technipion contains only down-type technifermions and is significantly lighter than the other pseudo Nambu-Goldstone bosons, (Casalbuoni et al., hep-ph/9809523)

3) a multiscale walking Technicolor model designed to reduce flavor-changing neutral currents, (Lane and Ramana, Phys. Rev. D 44 (1991) 2678.)

4) low-scale Technicolor model (the Technicolor Straw Man model) with many weak doublets of technifermions, in which the second-lightest technipion $P'$ is the state relevant for our study (the lightest, lacks the anomalous coupling to gluons) (Lane, hep-ph/9903369)

The models have different values of the technipion decay constant $F_P$, related to $N_D$ of weak technifermion doublets contributing to EWSB:

$$F_P^{(1)} = \frac{v}{2}, \quad F_P^{(2)} = v, \quad F_P^{(4)} = \frac{v}{\sqrt{10}}, \quad F_P^{(3)} = \frac{v}{4}$$
Technicolor enhancement factor for production via $gg$

Technipions couple anomalously to pairs of gauge bosons

$$N_{TC} A_{V_1 V_2} \times \frac{g_1 g_2}{8\pi^2 F_P} \times \epsilon_{\mu\nu\lambda\sigma} k_1^\mu k_2^\nu \epsilon_1^\lambda \epsilon_2^\sigma$$

Thus, the technipion decay width to gluons depends on the anomaly factor $A_{gg}$ and $F_P$

$$\Gamma(P \rightarrow gg) = \frac{m_P^3}{8\pi} \left( \frac{\alpha_s N_{TC} A_{gg}}{2\pi F_P} \right)^2$$

<table>
<thead>
<tr>
<th></th>
<th>1) one-family</th>
<th>2) variant one-family</th>
<th>3) multiscale</th>
<th>4) low-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{gg}$</td>
<td>$\frac{1}{\sqrt{3}}$</td>
<td>$\frac{1}{\sqrt{6}}$</td>
<td>$\sqrt{2}$</td>
<td>$\frac{1}{\sqrt{3}}$</td>
</tr>
<tr>
<td>$A_{\gamma \gamma}$</td>
<td>$-\frac{4}{3\sqrt{3}}$</td>
<td>$\frac{16}{3\sqrt{6}}$</td>
<td>$\frac{4\sqrt{2}}{3}$</td>
<td>$\frac{34}{9}$</td>
</tr>
</tbody>
</table>

Enhancement of the $gg$ production rate relative to the SM Higgs is

$$\kappa_{gg \ prod} = \frac{\Gamma(P \rightarrow gg)}{\Gamma(h \rightarrow gg)} = \frac{9}{4} N_{TC}^2 A_{gg}^2 \frac{v^2}{F_P^2}$$
Technicolor enhancement factor for production via $b\bar{b}$

Technipions couple to $b$ quarks through extended technicolor (ETC) interactions.

$$\Gamma(P \rightarrow b\bar{b}) \approx \frac{3m_f^2 m_P}{8\pi F_P^2}$$

In these technicolor models, the enhancement in $P$ production via $b\bar{b}$ (over SM Higgs production via $b\bar{b}$) is smaller than the enhancement in the $gg$ channel.

$$\frac{\kappa_{gg \ prod}}{\kappa_{bb \ prod}} \approx \frac{9}{4} N_{TC}^2 A_{gg}^2$$

The overall production enhancement is therefore (for $M_P = 130$ GeV):

<table>
<thead>
<tr>
<th></th>
<th>1) one family</th>
<th>2) variant one-family</th>
<th>3) multiscale</th>
<th>4) low scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\kappa_{gg \ prod}^P$</td>
<td>48</td>
<td>6</td>
<td>1200</td>
<td>120</td>
</tr>
<tr>
<td>$\kappa_{bb \ prod}^P$</td>
<td>4</td>
<td>0.67</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>$\kappa_{prod}^P$</td>
<td>47</td>
<td>5.9</td>
<td>1100</td>
<td>120</td>
</tr>
</tbody>
</table>
The main difference is the lack of a technipion decay to $W$ bosons, which is generally made up for by an increased branching fraction into $gg$. Below, we take $M_P = 130$ GeV.

<table>
<thead>
<tr>
<th>Decay Channel</th>
<th>1) one family</th>
<th>2) variant one family</th>
<th>3) multiscale</th>
<th>4) low scale</th>
<th>SM Higgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b\bar{b}$</td>
<td>0.60</td>
<td>0.53</td>
<td>0.23</td>
<td>0.60</td>
<td>0.53</td>
</tr>
<tr>
<td>$c\bar{c}$</td>
<td>0.05</td>
<td>0.0</td>
<td>0.03</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>$\tau^+\tau^-$</td>
<td>0.03</td>
<td>0.25</td>
<td>0.01</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>$gg$</td>
<td>0.32</td>
<td>0.21</td>
<td>0.73</td>
<td>0.32</td>
<td>0.07</td>
</tr>
<tr>
<td>$\gamma\gamma$</td>
<td>$2.7 \times 10^{-4}$</td>
<td>$2.9 \times 10^{-3}$</td>
<td>$6.1 \times 10^{-4}$</td>
<td>$6.4 \times 10^{-3}$</td>
<td>$2.2 \times 10^{-3}$</td>
</tr>
<tr>
<td>$W^+W^-$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Technipion enhancement factors and $\sigma(pp/p\bar{p} \rightarrow P \rightarrow xx)$

Comparison of the production and decay columns below shows that most of the total enhancement of the cross-section relative to the SM comes from the production rate. Below, we take $M_P = 130$ GeV.

<table>
<thead>
<tr>
<th>Model</th>
<th>Decay mode</th>
<th>$\kappa_{\text{prod}}^P$</th>
<th>$\kappa_{\text{dec}}^P$</th>
<th>$\kappa_{\text{tot/xx}}^P$</th>
<th>$\sigma$ at Tevatron</th>
<th>$\sigma$ at LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) one family</td>
<td>$b\bar{b}$</td>
<td>47</td>
<td>1.1</td>
<td>52</td>
<td>14 pb</td>
<td>890 pb</td>
</tr>
<tr>
<td></td>
<td>$\tau^+\tau^-$</td>
<td>47</td>
<td>0.6</td>
<td>28</td>
<td>0.77 pb</td>
<td>48 pb</td>
</tr>
<tr>
<td></td>
<td>$\gamma\gamma$</td>
<td>47</td>
<td>0.12</td>
<td>5.6</td>
<td>.0064 pb</td>
<td>0.4 pb</td>
</tr>
<tr>
<td>2) variant</td>
<td>$b\bar{b}$</td>
<td>5.9</td>
<td>1</td>
<td>5.9</td>
<td>1.8 pb</td>
<td>100 pb</td>
</tr>
<tr>
<td>one family</td>
<td>$\tau^+\tau^-$</td>
<td>5.9</td>
<td>5</td>
<td>30</td>
<td>0.84 pb</td>
<td>52 pb</td>
</tr>
<tr>
<td></td>
<td>$\gamma\gamma$</td>
<td>5.9</td>
<td>1.3</td>
<td>7.7</td>
<td>.0087 pb</td>
<td>0.55 pb</td>
</tr>
<tr>
<td>3) multiscale</td>
<td>$b\bar{b}$</td>
<td>1100</td>
<td>0.43</td>
<td>470</td>
<td>130 pb</td>
<td>8000 pb</td>
</tr>
<tr>
<td></td>
<td>$\tau^+\tau^-$</td>
<td>1100</td>
<td>0.2</td>
<td>220</td>
<td>6.1 pb</td>
<td>380 pb</td>
</tr>
<tr>
<td></td>
<td>$\gamma\gamma$</td>
<td>1100</td>
<td>0.27</td>
<td>300</td>
<td>0.34 pb</td>
<td>22 pb</td>
</tr>
<tr>
<td>4) low scale</td>
<td>$b\bar{b}$</td>
<td>120</td>
<td>1.1</td>
<td>130</td>
<td>36 pb</td>
<td>2200 pb</td>
</tr>
<tr>
<td></td>
<td>$\tau^+\tau^-$</td>
<td>120</td>
<td>0.6</td>
<td>72</td>
<td>2 pb</td>
<td>120 pb</td>
</tr>
<tr>
<td></td>
<td>$\gamma\gamma$</td>
<td>120</td>
<td>2.9</td>
<td>350</td>
<td>0.4 pb</td>
<td>25 pb</td>
</tr>
</tbody>
</table>
Visibility of Technipions: $\tau\tau$ and $\gamma\gamma$ channels
Visibility of Technipions: $\tau\tau$ and $\gamma\gamma$ channels

Predicted Tevatron reach, based on the $h_{SM} \rightarrow \tau^+\tau^-$ studies by A.B., T. Han, R. Rosenfeld, hep-ph/0204210 and on the $h_{SM} \rightarrow \gamma\gamma$ studies by S. Mrenna and J. D. Wells, hep-ph/0001226
Visibility of Technipions: $\tau\tau$ and $\gamma\gamma$ channels

Predicted LHC reach, based on the $h_{SM} \to \tau^+\tau^-$ studies by D.Cavalli et al, hep-ph/0203056 and on the $h_{SM} \to \gamma\gamma$ studies by R. Kinnunen, S. Lehti, A. Nikitenko and P. Salmi, hep-ph/0503067
The Meaning of "Higgs": SUSY vs. Technicolor

- The Tevatron and LHC have the potential to observe the light (pseudo) scalar states of both supersymmetric and dynamical symmetry breaking (DSB) models in the $\tau^+\tau^-$ channel.

- In the MSSM, the $\tau^+\tau^-$ channel is enhanced but the $\gamma\gamma$ channel is suppressed: even the LHC would not observe the $\gamma\gamma$ signature.

- In the dynamical symmetry breaking models studied, we expect simultaneous enhancement of both the $\tau^+\tau^-$ and $\gamma\gamma$ channels. Even at the Tevatron we may observe technipions via the $\gamma\gamma$ signature at the $5\sigma$ level for Models 3 and 4.

- The LHC collider, which will have better sensitivity to the signatures under study, will be able to find the technipions of all four DSB models.

- In the MSSM, scalar production via $b\bar{b}$ fusion can rival $gg$ fusion; in DSB models, $b\bar{b}$ fusion should be negligible. Exploiting this difference (e.g. study $H$ production in association with $b$-quarks) may prove useful.
Results from CDF and D0 (from Anton Anastassov)

\[ \tan \beta \]

\[ m_A (\text{GeV}) \]

\[ \mu = -200 \text{ GeV}, \ M_2 = 200 \text{ GeV}, \ m_\chi = 0.8 \ M_{\text{SUSY}} \]
\[ M_{\text{SUSY}} = 1 \text{ TeV}, \quad \chi_i = \sqrt{\xi} M_{\text{SUSY}} (m^\text{max}_h), \quad \chi_i = 0 \ (\text{no-mixing}) \]

\[ \text{gg+bb} \rightarrow A+H+h, \ Tevatron, \sqrt{s} = 1.96 \text{ TeV} \]

CDF Run II  310 pb\(^{-1}\)
MSSM Higgs\(\rightarrow\tau\tau\) Search
Preliminary

CDF
D\(\xi\)
LEP 2
no mixing
no mixing

\[ m_h^\text{max} \]

\[ m_h \]

\[ \mu < 0 \]
Conclusions

- Searches for a light Standard Model Higgs boson at Tevatron Run II and CERN LHC can also shed light on physics beyond the SM.

- New scalar and pseudo-scalar states predicted in both supersymmetric and dynamical models can have enhanced visibility in standard $\tau^+\tau^-$ and $\gamma\gamma$ search channels making them potentially discoverable at both Run II and the LHC.

- The enhancement arises largely from increases in the production rate

- The model parameters exerting the largest influence on the enhancement size are $\tan\beta$ in the case of the MSSM and $N_{TC}$ and $F_P$ in the case of dynamical symmetry breaking.

- Observation of $pp/p\bar{p} \rightarrow H \rightarrow \tau^+\tau^-$ covers a large parameter space

- $pp/p\bar{p} \rightarrow H \rightarrow \gamma\gamma$ may cleanly distinguish the scalars of supersymmetric models from those of dynamical models.