Discussion on the Tevatron-LHC connection

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Tevatron physics in preparation for the LHC

• At the Tevatron: unique potential for learning from data to improve our simulations and ultimately real data analysis at the LHC.

For example, the Run II hadronic environment, with multiple interactions per crossing, has implications for b-tagging, tau reconstruction, lepton isolation, jet reconstruction, MET.

• We need to understand how to scale up the messy realities of current Run II analyses into the even more messy realities of the LHC.

• We also need to understand how Run II results (precision measurements, discoveries and constraints) will impact LHC search strategies, taking into account the latest theoretical developments in Higgs physics, SUSY, etc.

As a kick off of the joint theory/experimental activities in preparation for LHC
$\Longrightarrow$ **3-day workshop at Fermilab in mid September (Sept.16-18, 2004)**

•The workshop will combine talks and working sessions, with the idea of initiating specific projects in these areas.

• This activity could eventually ramp up into a year-long working group oriented series of workshops in 2005/6

How can the Tevatron help us understand LHC data in the future?

- **By learning how to improve on measurements which will be helpful in extracting the physics more precisely at both colliders**

– understanding how our calculations of cross sections for important backgrounds to new physics: $b\bar{b}$, $W/Zb\bar{b}$, $t\bar{t}$, single top, match reality

– testing phenomenological models of fragmentation: how quarks and gluons turn into hadrons

– learning more about the impact of underlying events: proton remnants and additional overlapping events

– Measurements of PDF's:

⋆ learning more about PDF's will be helpful in computing cross sections both for better understanding electroweak and QCD physics and for predicting backgrounds which might be harder to estimate from control samples. This in turn can be crucial in extracting new physics signatures and parameters.

⋆ possibly measuring heavy flavour PDF's from $c\gamma$, $b\gamma$, $c/b + jets$ production.

– Measure $t\bar{t}$ kinematics: distribution of jets in $t\bar{t}$ events

- **By developing analysis techniques based on actual data, which will give us experience in using similar techniques at the LHC:**
  $\Longrightarrow$ improve on signal to background ratio in many different ways

- developing better b-tagging techniques in hadron collisions with background track from other interactions

- same for tau reconstruction, including hadronic decays

- reconstruction of forward jets. How well one can measure jet energy and direction?

- dijet mass resolution: methods to improve on $b\bar{b}$ mass resolution at Tevatron (QCD, parton shower considerations in the evolution of jets, cuts) may be helpful in dealing with degradation of dijet mass resolution at the LHC high luminosity enviroment.

- Studies of lepton isolation in hadron colliders with many interactions per bunch

- Missing energy measurements: resolution and calibration

Usually one is interested in events with *large* $\not\!\!E_T$ – the focus is on the high end of the $\not\!\!E_T$ distribution:
$\not\!\!E_T$ resolution has long tails. Leading contributors to the tails:

1. additional interactions in the same bunch crossing

2. scattering of the proton remnants (always forward?)

3. gaps & holes in the acceptance / detector coverage, failures of individual channels

All these will be difficult to simulate reliably.

- Photon ID: **jets faking photons** $\rightarrow$ how often does a high energy parton fragment into a neutral pion (which will look like a photon)?
Measure these directly at the Tevatron

- **By acquiring training in physics analyses in preparation for the LHC**

- $Z \rightarrow \tau^+\tau^-$, $b\bar{b}$ in preparation for $H \rightarrow \tau^+\tau^-$, $b\bar{b}$

- precision measurements at the Tevatron $\Longrightarrow$ m_t and M_W: similar techniques will be used at LHC for these measurements

- Run II discoveries + exclusions will impact LHC searches for new physics: For example, Run II measurements in the Bs system will constrain SUSY models $\rightarrow$ impact on the allowed parameter space for the heavier partners of the Higgs: a major physics target for LHC searches
Direct detection of SUSY and Higgs exclusion or “evidence”!

What Can We Learn from RUN 2?

– Precision measurements:

- top quark mass: $\delta M_t \simeq 3$ GeV with 2 fb^{-1}
- W mass: $\delta M_W \simeq 30$ MeV with 2 fb^{-1}

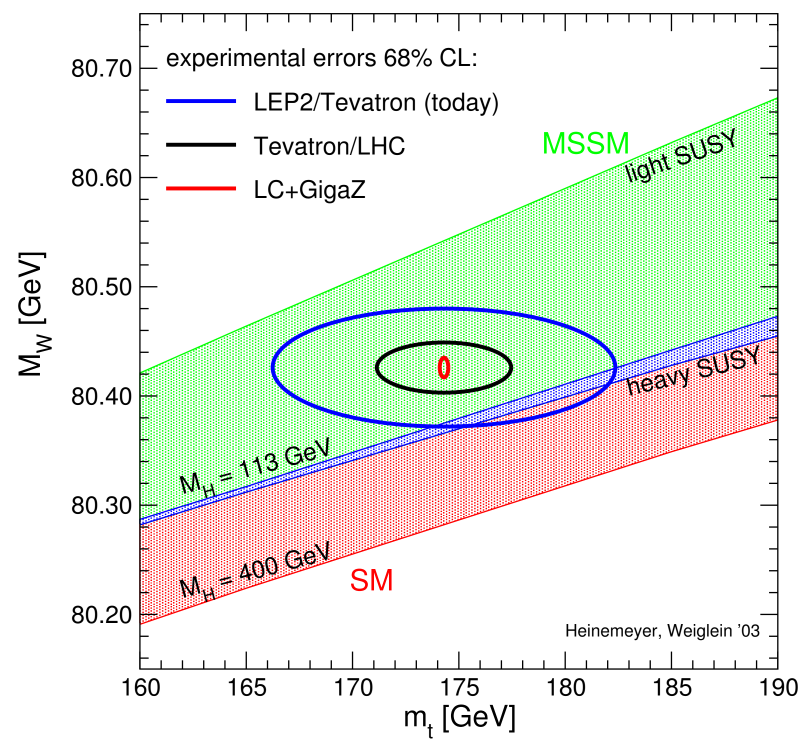
high precision for M_t is important to

$\Longrightarrow$ exploit precision on M_W in the context of electroweak precision measurements

M_t–M_W–M_H Correlation

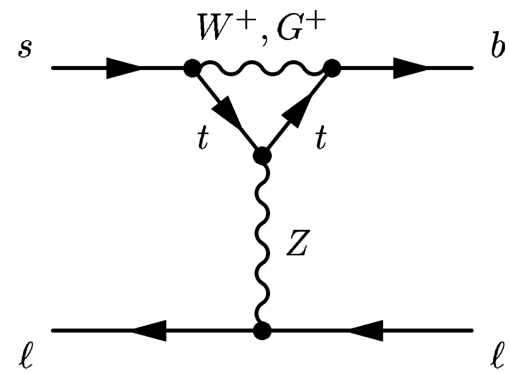
- direct M_t and M_W measurements from LEP and the Tevatron
- Indirect M_t and M_W determination from SM fit to precision data (LEP, SLD, νN)
- SM relationship for M_t–M_W–M_H
  $\Longrightarrow$ crucial information on M_H

$\Longrightarrow$ A light SM Higgs Boson strongly favored by data



$B_s \to \mu^+\mu^-$ as a probe of $\tan\beta$ at the Tevatron

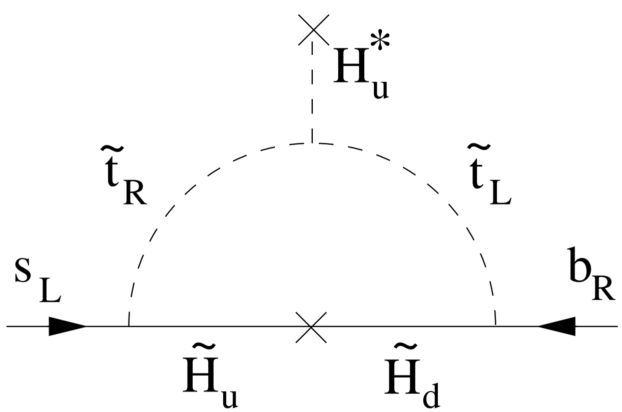
SM sample diagram:



SM amplitude $\propto$ $V_{ts} \frac{m_\mu}{M_W}$

$Br(B \to \mu^+\mu^-)_{\rm SM} = (3.8 \pm 1.0) \times 10^{-9}$

- In the MSSM, with two Higgs doublets, the Higgs Mediated contribution can put this BR at the reach of the Tevatron!



After SUSY breakdown, new contributions to d-type quark masses are generated even in a Minimal Flavor Model (CKM-induced)

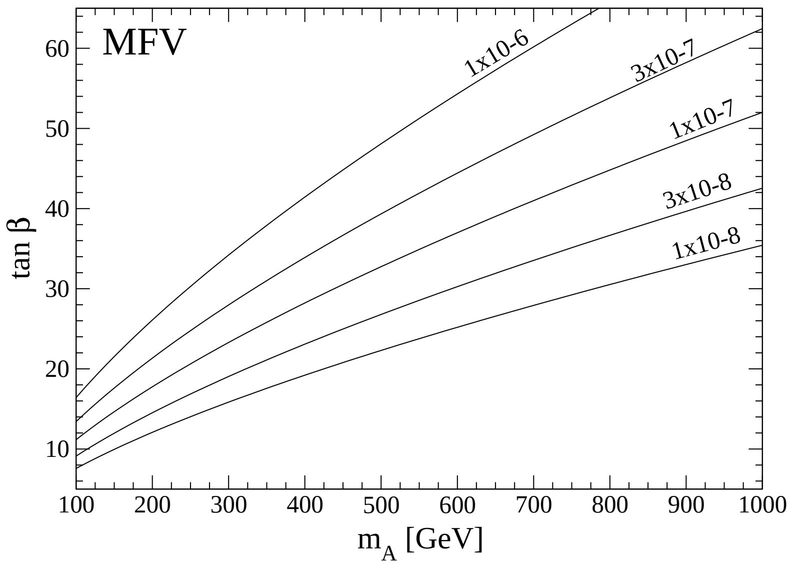
$Br(B \to \mu^+\mu^-)_{\rm MSSM} \propto \tan^6\beta \frac{1}{M_{A^0}^2} f(\mu A_t, M_{\tilde{t}_i}, M_{\tilde{\chi}_i^+})$

where $f \to$ const. $\neq 0$ for $M_{\rm SUSY} \to \infty$.

Babu, Kolda

$\Rightarrow$ branching fraction can be enhanced by three orders of magnitude!

Contours of Maximun allowed value of BR($B_s \to \mu\mu$) as a function of M_A and $\tan\beta$.



- $Br(B_s \to \mu^+\mu^-) < 2.6 \cdot 10^{-6}$ from Run 1.
- Single event sensitivity at Run 2 is 10^{-8} for 2 fb^{-1}

Kane, Kolda, Lennon

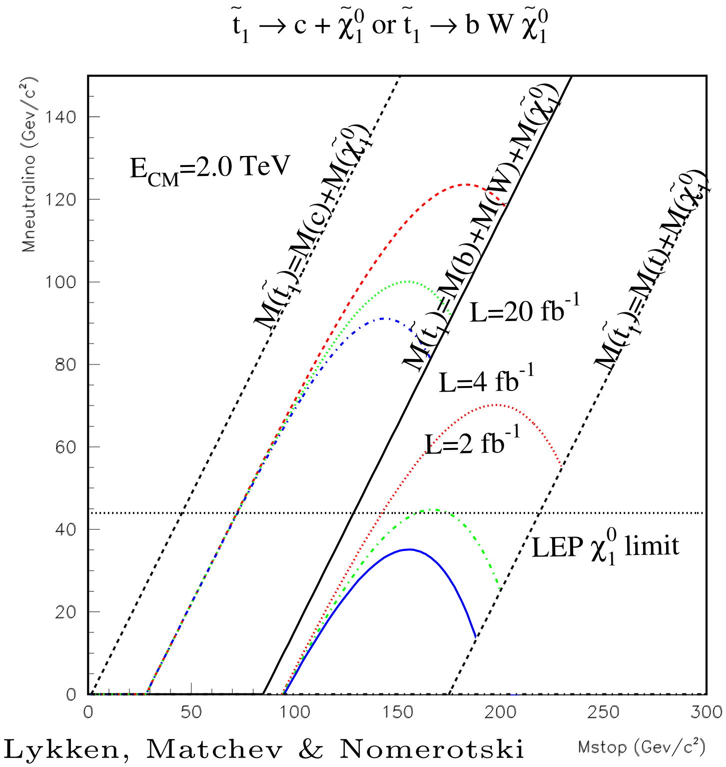
If a signature is observed at the Tevatron $\Longrightarrow$ lower bound on the value of $\tan\beta$

$$\tan\beta > 11 \left(\frac{M_A}{100GeV}\right)^{2/3} \left[\frac{Br(B_s \to \mu^+\mu^-)}{10^{-7}}\right]^{1/6}$$

Interesting to study direct reach in M_A via $b\bar{b}$ A/H production for large $\tan\beta$ and reach in $Br(B_s \to \mu^+\mu^-)$ for different sets of MSSM paraneters

Stop Searches and $\not\!\!E_T$

In many SUSY models $\longrightarrow$ $\tilde{t}$**'s quite light**



Demina, Lykken, Matchev & Nomerotski

- When kinematically allowed,

$$\tilde{t}_1 \to b\tilde{\chi}_1^{\pm(*)} \to b\tilde{\chi}_1^0 f\bar{f}' \text{ with } f\bar{f}' = \ell\bar{\nu} \text{ or } q\bar{q}'$$

Signals: 2b jets + 2 W's/2l's + $\not\!\!E_T$

Selection: b-jet + jet + l + $\not\!\!E_T$, 2l's + jet + $\not\!\!E_T$

- Otherwise,

$$\tilde{t}_1 \to c\tilde{\chi}_1^0 \quad \text{via } b\widetilde{\chi}_1^{\pm} \text{ loop}$$

Signal/Selection: 2 c-jets + $\not\!\!E_T$

- Light stops as required by Electroweak Baryogenesis:

$$m_{\tilde{t}_1} \leq m_t \Longrightarrow \text{within Tevatron reach}$$

- To make this compatible with the neutralino LSP being the dark matter candidate that explains Ω_{CDM} observed by WMAP $\rightarrow$ requires neutralino-stop co-anihilation

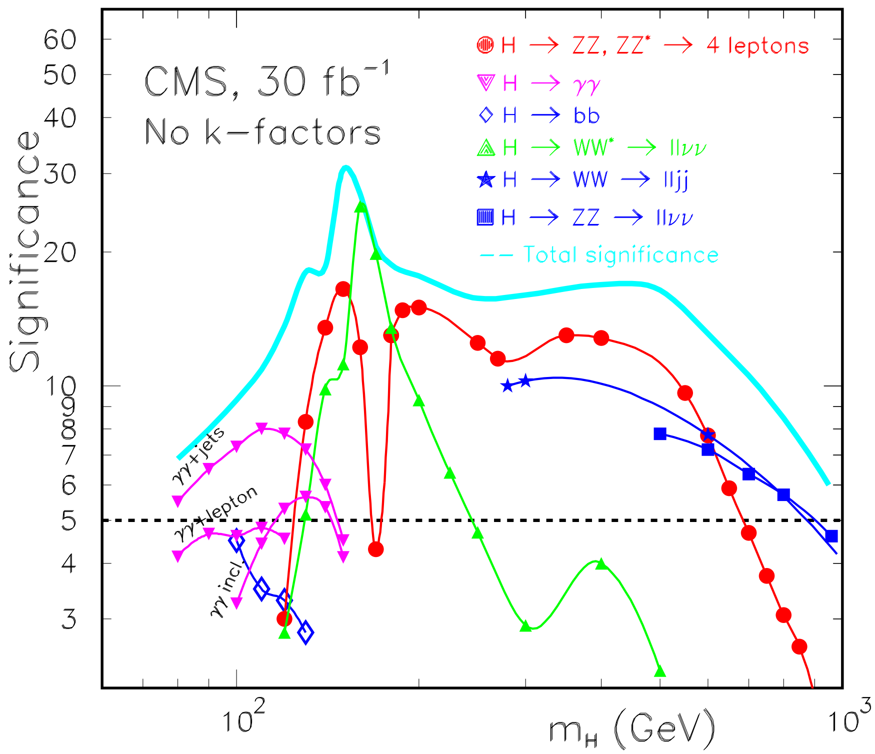
This demands $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \leq 30$ GeV

Challenging for hadron colliders! $\Longrightarrow$ Need to improve on $\not\!\!E_T$ measurements.

One of the main goals of the LHC

$\Longrightarrow$ elucidate the Electroweak Symmetry breaking mechanism Most likely via Higgs boson discovery

- SM Higgs $\rightarrow$ expected mass below 200 GeV



mass regions –

- m_H in the range $2\,M_Z$ – 600 GeV
  best channel is $H \rightarrow ZZ \rightarrow 4\ell$
- $m_H > 600$ GeV
  $H \rightarrow ZZ \rightarrow \ell^+\ell^-\nu\bar{\nu}$ and
  $H \rightarrow WW \rightarrow \ell\nu JJ$
  more demanding :
- $m_H < 2\,M_Z$ (esp. below 130 GeV)

need combination of three channels:

$H \rightarrow \gamma\gamma, \qquad H\,t\bar{t} \rightarrow b\bar{b}\,t\bar{t},$

$q\bar{q}\,H \rightarrow q\bar{q}\,\tau^+\tau^-/WW^*$

to achieve 5σ discovery with the first 10-30 fb^{-1}

- Higgs Bosons in the Minimal Supersymmetric Extension of the Standard Model (MSSM)

– many different channels for H, A & $H^{\pm}$

– but full coverage assured only for h