Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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(FROM HERA AND THE TEVATRON TO THE LHC)

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Searches in the $\not{E}_T + b\bar{b}$ channel with the CDF data

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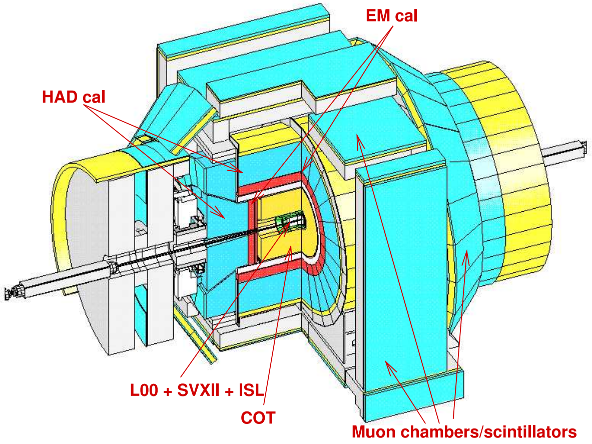


Overview of the talk

The talk will cover my contribution to different analyses involving the indicated signature.

- **Motivation for the signature**
- **Description of experimental tools**
  - $\Rightarrow$ **Reconstruction of $\not\!\!E_T$**
  - $\Rightarrow$ **Trigger challenge for low $\not\!\!E_T$ events**
  - $\Rightarrow$ **Identification of b-jets at CDF**
- **And the results of the analyses**
  - $\Rightarrow$ **Search of sbottom and gluino.**
  - $\Rightarrow$ **Search of the Higgs boson in $ZH \rightarrow \nu\bar{\nu}b\bar{b}$**

With some conclusions and plans for the future of this kind of searches at Tevatron (mainly for CDF).

Performing searches at Tevatron

Standard Model (SM): big success during the last 30 years to explain the experimental results in collider physics.

However, still some **open questions about Nature:** The origin of mass, three generations, composition of Dark matter, . . .

and some motivations from theory to "justify" the success of the SM: Mass hierarchy problem, explain Universe from first principles: e.g. how did antimatter disappear?, . . .

From the point of view of the experiment, the main limitation is the small cross section of the processes involving *New Physics*.

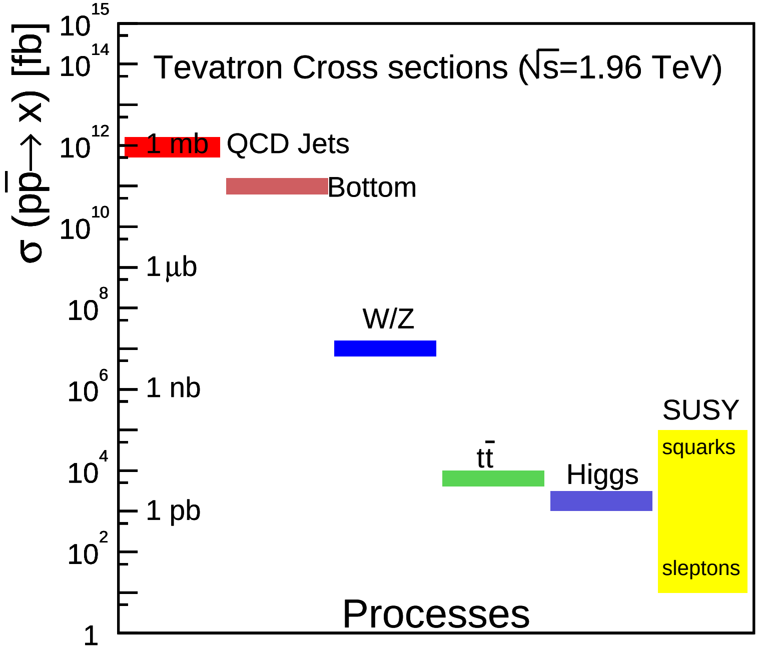
It is needed to select "distinctive" signatures:

⇒ Enhanced cross sections on high-p_T tails

⇒ Enhanced production of particles (leptons, b-quarks, . . .)

⇒ Production of new particles (observed as resonances or through "exotic" decays)

⇒ Observation of $\not{E}_T$ (transverse momentum not conserved) due to weakly-interacting particles escaping detection.



The $\not\!\!E_T + b\bar{b}$ Signature

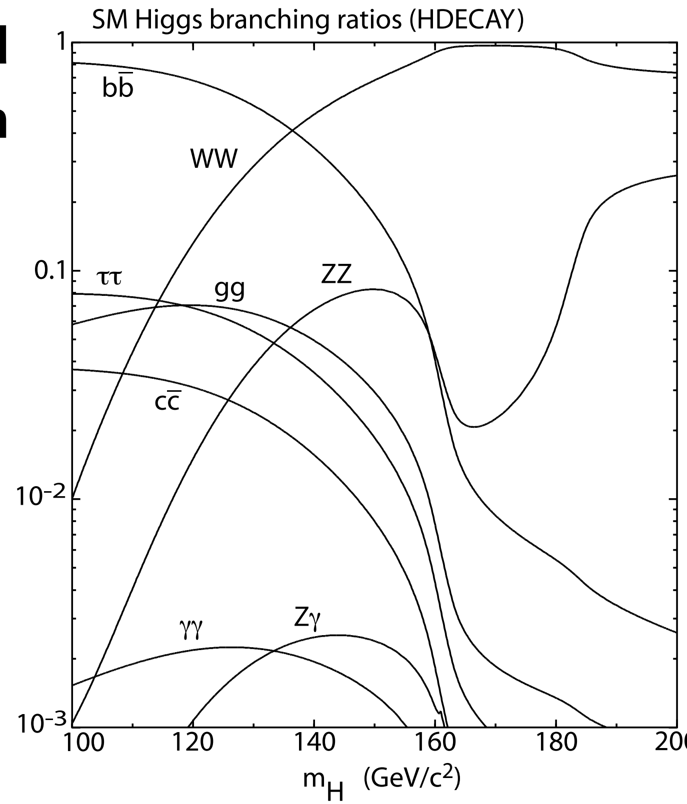
- At Tevatron searches, the distinctive signatures are built from objects which are hard to produce in typical hadron collisions:

$\Rightarrow$ Leptons (e,μ) in the final state, usually being isolated.

$\Rightarrow$ Large imbalance in visible transverse momentum ($\not\!\!E_T$)

Several extensions of the SM introduce weakly-interacting particles which may escape detection (as neutrinos do).

$\Rightarrow$ Reconstruction of b-jets or hadronic τ's, motivated by the preference of the third generation (heavier) in several models (e.g. the Higgs boson).



Some examples of interest for the $\not\!\!E_T + b\bar{b}$ signature:

– sbottom in Rp-conserving SUSY

With the decay $\tilde{b} \rightarrow b\tilde{\chi}$ events are expected to present $\not\!\!E_T$ (from stable $\tilde{\chi}$) and b-jets

– Low-mass Higgs in the $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ channel

Presence of neutrinos help to distiguish events from more commen processes, especially for trigger purposes

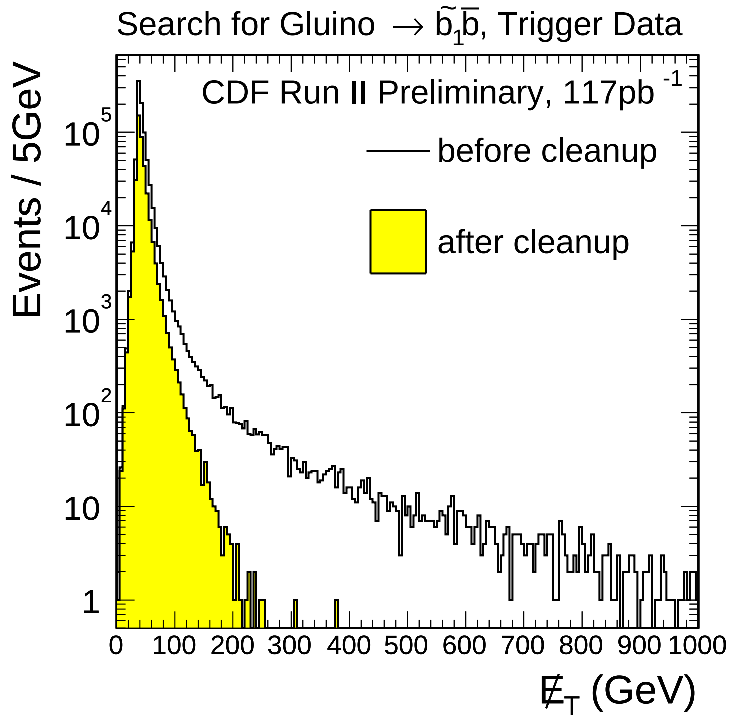
Selecting the sample: $\not\!\!E_T$ reconstruction

Due to its interest in searches, the samples with $\not\!\!E_T$ are of big importance for the Tevatron program.

- **It is hard to select events at the trigger level having large $\not\!\!E_T$ due to several limitations (mainly the presence of events not directly related to $p\bar{p}$ collisions).**

- **It is necessary to apply several "clean-up cuts" to select good events in the triggered samples. Most of these cuts cannot be applied online.**

- **Furthermore, calibrations and vertex reconstruction (performed offline) introduce differences in the reconstruction which make triggers hard to understand.**

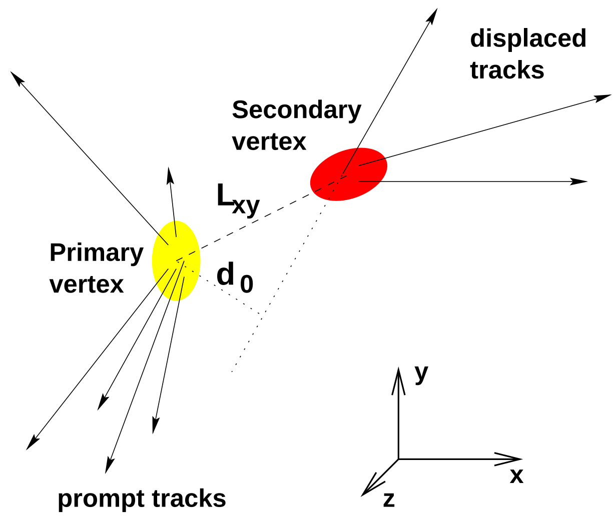


It should be noted that when leptons are not present, events with large $\not\!\!E_T$ need to be identified using triggers based on $\not\!\!E_T$ reconstruction.

In addition to the "already-understood" problems, in the incoming future we have an additional trouble: the reconstruction (especially online but also offline) of $\not\!\!E_T$ in multiple-collision environment (pile-up).

Identifying b-jets (I)

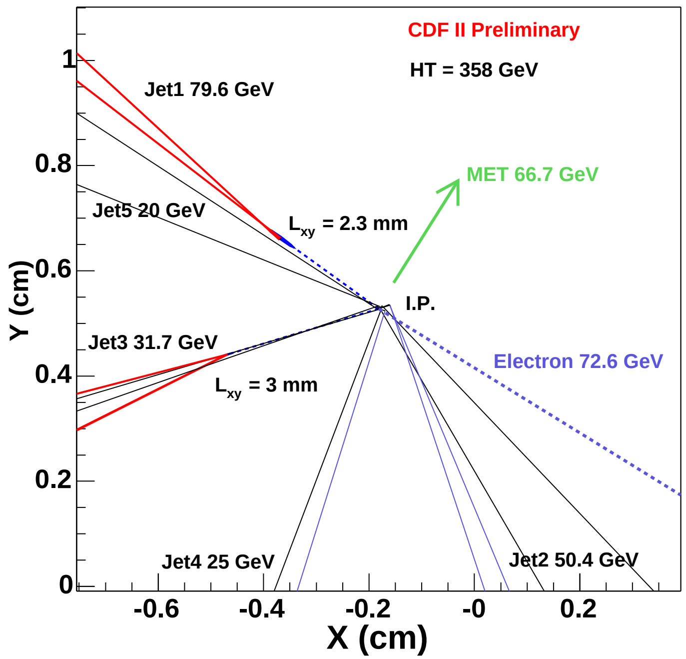
The standard way (at CDF) to identify jets originating from heavy quarks is to re-construct a secondary vertex inside the jet.



- For that we use tracks of a minimum-quality properties.

- A vertex must be reconstructed out of these tracks and the fit should be relatively good.

- Selection in the displacement of this "secondary vertex" wrt the primary vertex (L_{xy}) allows to distinguish jets from b's, c's or other partons



As obvious, among the selected (tagged) jets there will be some misidentified jets. The amount of events which this misidentified b-jets is estimated using statistical techniques based mostly on data.

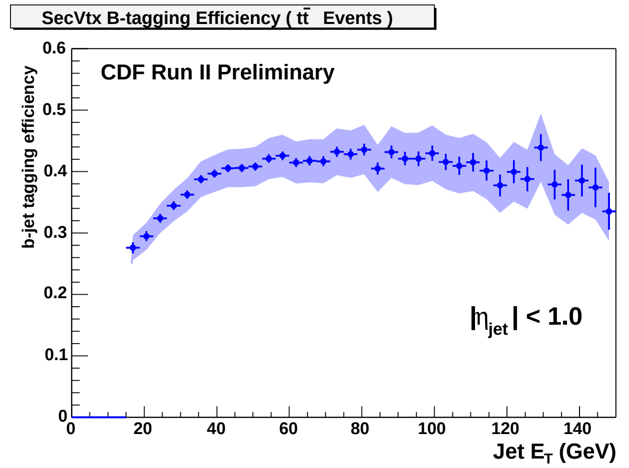
Identifying b-jets (II)

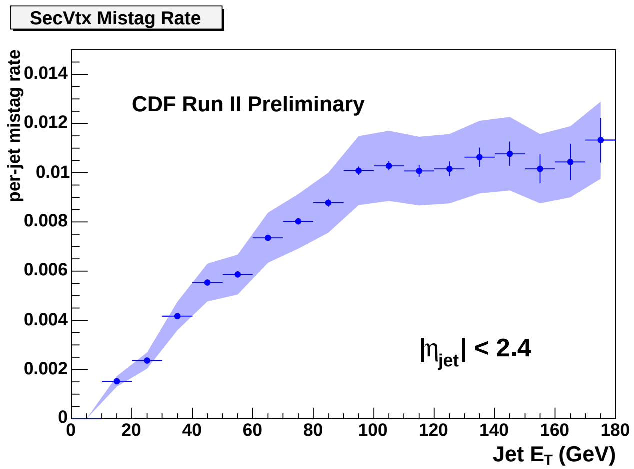
● The use of any track in the vertex reconstruction increases the chance of finding a vertex, but it also increases the chance of misindentification of jets.

The necesssary balance explain the two strategies at CDF during Run II:

⇒ At the beginning, tracks were selected with hard cuts. However any reconstructed secondary vertex was accepted.

⇒ After improving alignment of silicon detectors (main limitation) and understanding of the reconstruction, track selection was loosened but vertex fits are more stringent.



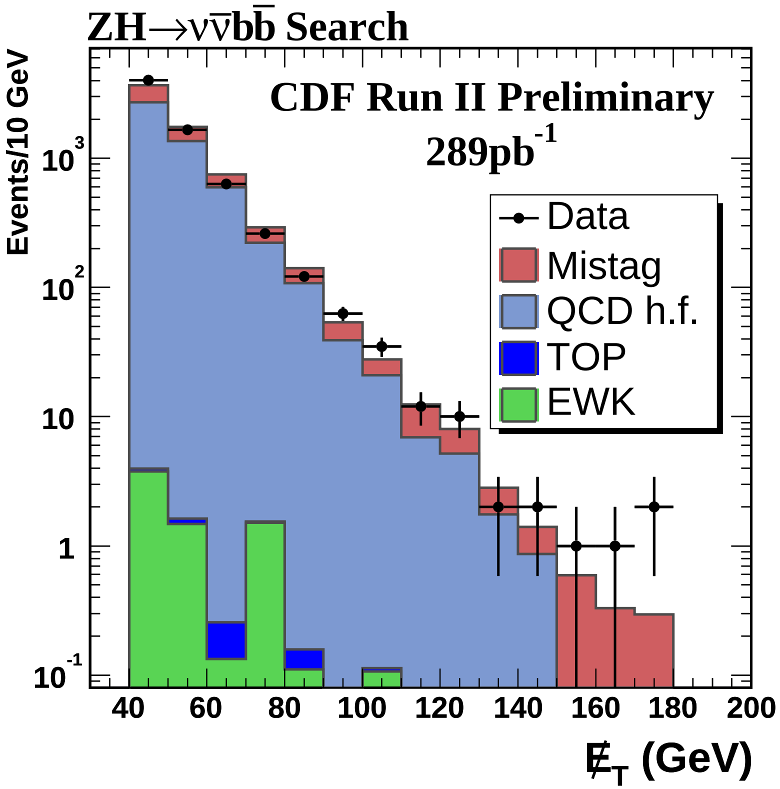


Currently, CDF is developing several algorithms based on displaced tracks (some with explicit vertex reconstruction) which would allow a more flexible use of the algorithm, which may be adapted in an analysis basis.

The high luminosity (i.e. pile-up) environment is going to be challenging also for high-p_T b-tagging since the algorithm gets confused when two interactions gets closer.

The $\not{E}_T$+ b-jet sample

- Selecting events with large $\not{E}_T$ (after offline corrections).
- The $\not{E}_T$ is reconstructed using the calorimeter towers and with respect to a well-identified vertex.
- and corrected as the jet energies are corrected (for detector effects).



⇒ When a b-tagged jet is required in the event, the sample is reduced to a easy-to-handle number of events.

⇒ Sample is dominated by QCD production of heavy-flavour jets (and mistags).

⇒ The largest complication of the analyses based on this sample is to understand the QCD background, especially as a function of $\not{E}_T$ Estimation of the QCD background from MC events is challenging due to the size of the required samples.

We are considering changing to some data-based strategy (as D0 is currently doing for the ZH analysis) keeping MC for cross-checks.

Estimation of the SM backgrounds

Although the sample is dominated by QCD multijet production before some optimization cuts, when these are applied, other SM backgrounds appear.

A $\Delta\phi$ cut between jets and the $\not{E}_T$ helps to reduce the "QCD" background (where the $\not{E}_T$ is mostly due to mismeasurement or semileptonic decays from heavy quarks).

The backgrounds are estimated as follows:

$\Rightarrow$ Contribution from misidentified heavy-flavour jets (mistags) is estimated using mostly data (MC is used to check normalization).

$\Rightarrow$ QCD production of heavy-flavour jets is estimated with MC and normalized in a QCD-dominated region (as shown before).

$\Rightarrow$ $t\bar{t}$ and single-top are estimated with MC and using the theoretical cross sections

$\Rightarrow$ Contribution of Electroweak processes (Z/W+jets) are estimated using MC.

It should be noted that Electroweak bosons may produce leptons. Neutrinos and muons may induce $\not{E}_T$.

In addition, three-prong τ's are sometimes identified as b-jets.

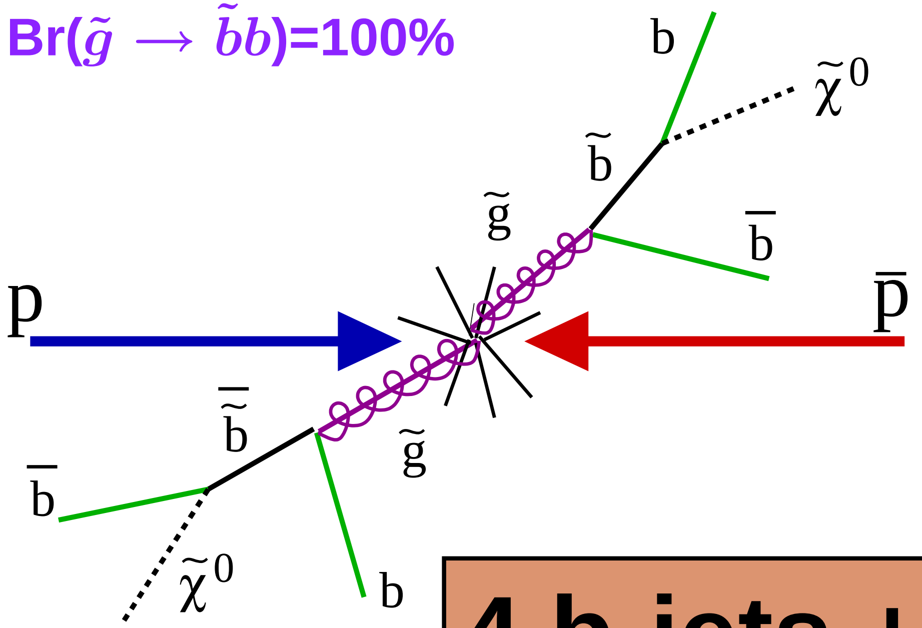
Searching for $\tilde{g} \rightarrow \tilde{b}b$ (I)

- **Direct s-bottom search suffers from SM backgrounds ($b\bar{b}$ production).**
- **A different approach has been considered.**

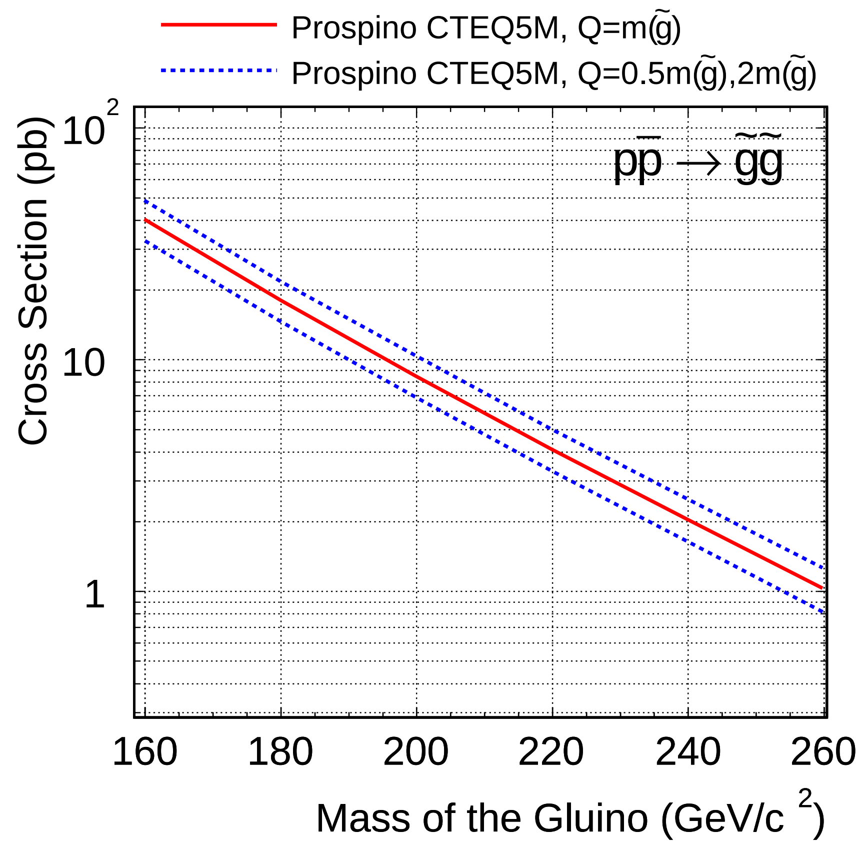
The idea is to search from s-bottom coming from gluino, which is the particle that is pair-produced in the collision (pro: larger cross section, for same mass).

The gluino will decay into a s-bottom/bottom pair in a decay chain which provides a clean signature.

Br($\tilde{g} \rightarrow \tilde{b}b$)=100%



4 b-jets + $\not{E}_T$



Searching for $\tilde{g} \rightarrow \tilde{b}b$ (II)

- **The analysis on gluino-pair production was designed to look for events as:**

$$p\bar{p} \Rightarrow \tilde{g}\tilde{g} + X \rightarrow (b\tilde{b}_1)(b\tilde{b}_1) + X \rightarrow (bb\tilde{\chi}_1^0)(bb\tilde{\chi}_1^0) + X$$

- **The signal region is defined by**

$\rightarrow$ $\not{E}_T > 80$ **GeV.**

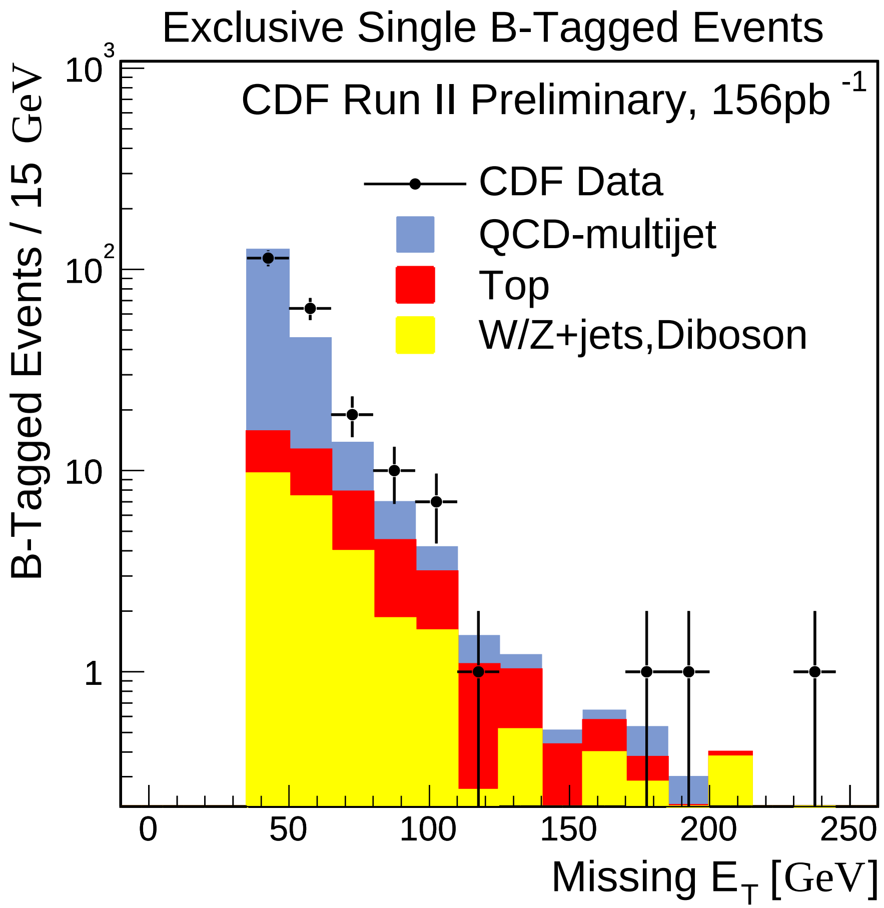
$\rightarrow$ **No isolated leptons**

(reduce Z/W+jets)

$\rightarrow$ **3 or more jets with**

$E_T > 15$ **GeV and** $|\eta| < 2$.

$\rightarrow$ **Specific cuts to reduce background from multijet production: cuts on azimuthal angle between jets and $\not{E}_T$.**

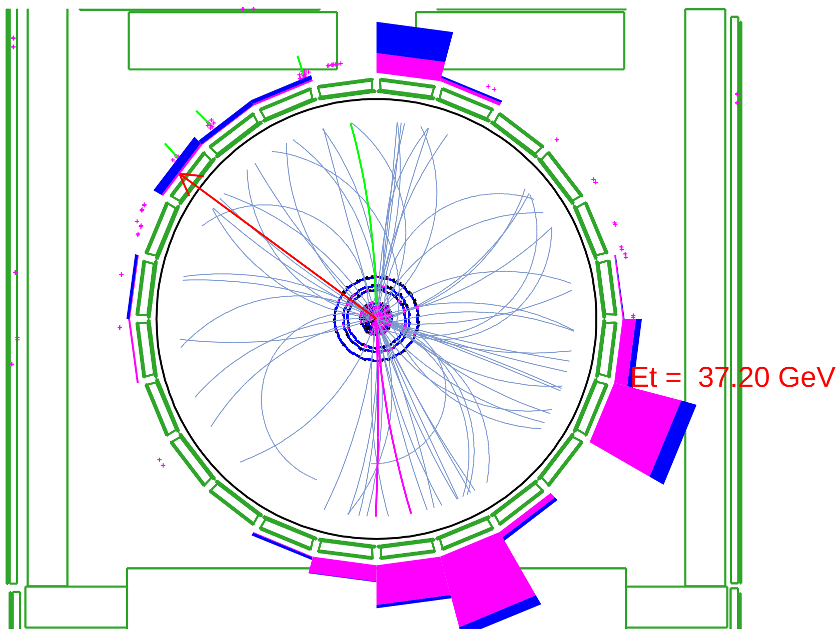


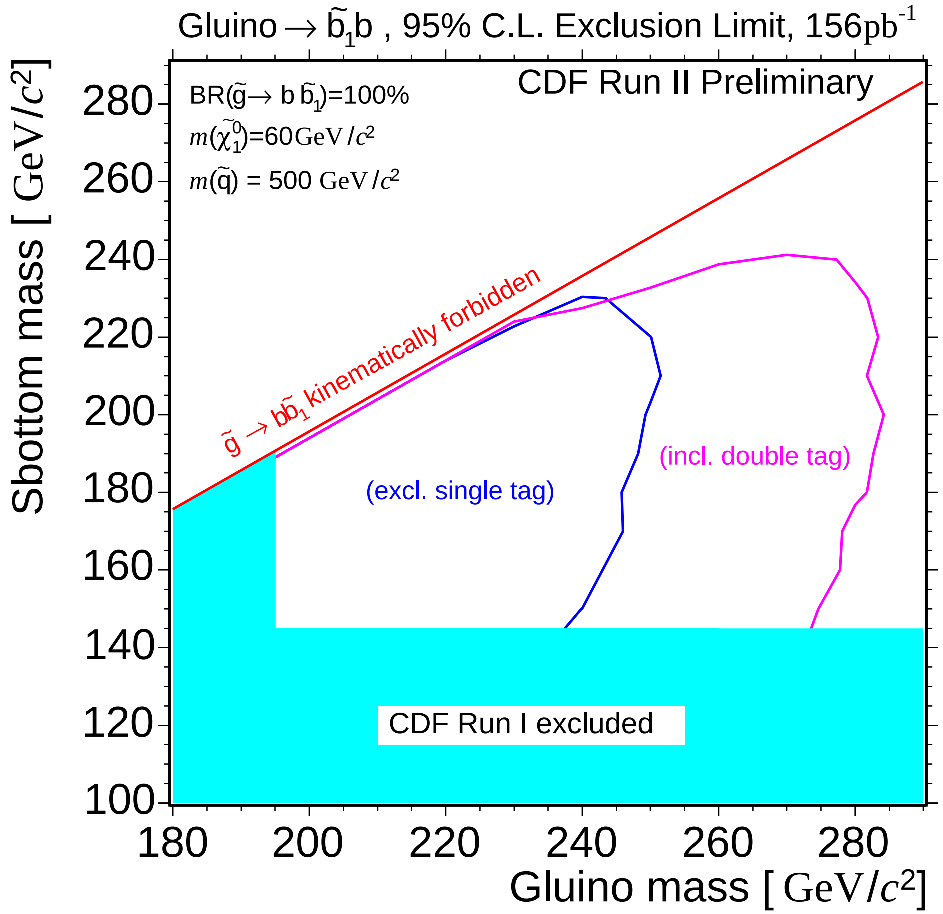
- **Further SM background is reduced by requiring more tagged b-jets.**

Searching for $\tilde{g} \to \tilde{b}b$ (III)

- Signal region separated in exclusive single-tag and inclusive double-tag bins.
- The requirement of a second tag reduces the background while keeping most of the signal due to the 4 b-jets that are expected in the signal.
- Data in agreement with expected Standard Model background.

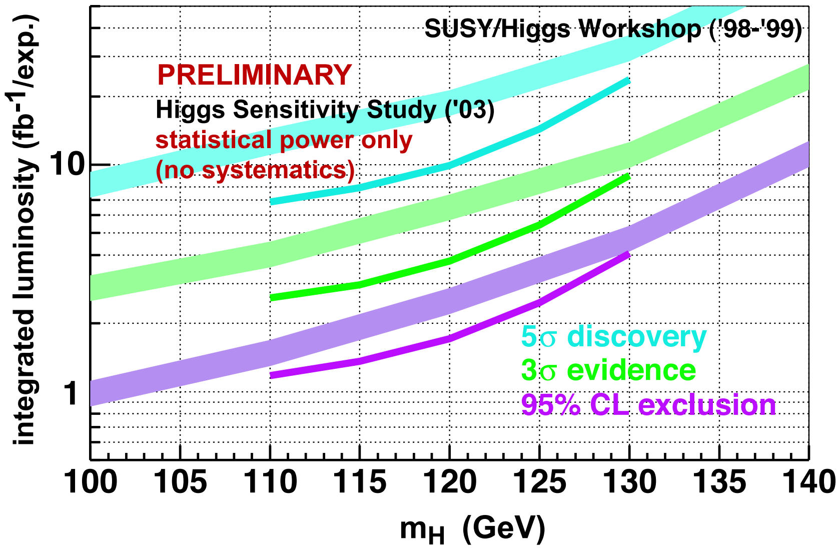
b-tags	Observed events	Expected background
=1	21	16.4 ± 3.7
$\geqslant 2$	4	2.6 ± 0.7





Seaching for the Higgs at Tevatron

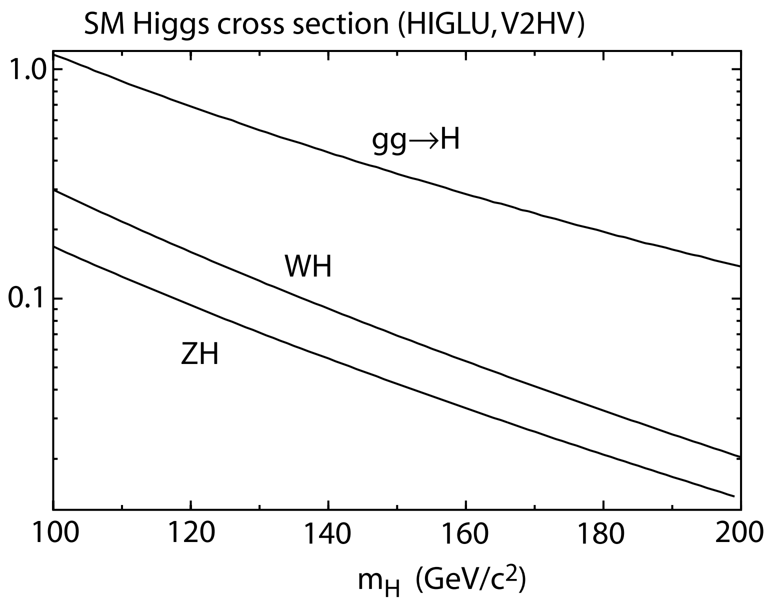
The search for the Higgs boson is very attractive at Tevatron due to the big motivation for the existence of this particle and with a low mass.



with the expected luminosity at Run II, direct observation of the Higgs is very challenging, although it should be possible to extend the exclusion limit beyond the LEP limit.

Concretely, we should be able to exclude the presence of the Higgs in the region where LEP experiments claimed some evidence (if Higgs is not there).

For this region of higher sensitivity, Higgs decay is dominated by $H \to b\bar{b}$



At Tevatron, the dominant process is inclusive Higgs production, but the observation of this events over the QCD background is not possible.

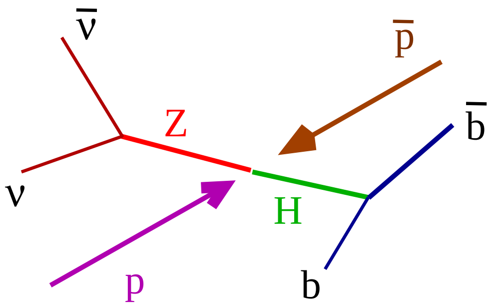
Associated production of a Higgs and a Weak boson has a smaller cross section (factor 7-8) but the identification of events is simplified due to the presence of leptons or $\not{E}_T$ in the final state.

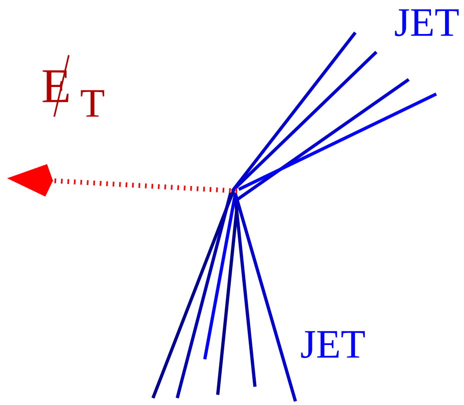
This is essential for online selection of the events (i.e. trigger level).

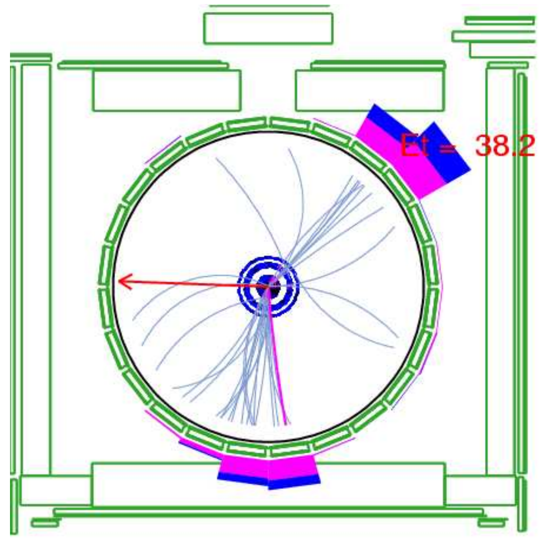
$ZH \to \nu\nu bb$ (I)

The production of a Higgs in association with a Z^0 boson may be observed as two jets and $\not\!\!E_T$ from the neutrino decay of the Z^0 (20% of the events).

Event topology allows the reduction of the QCD-multijet contribution for which the $\not\!\!E_T$ is mostly due to mismeasurement of the jet energy or semileptonic decays of heavy quarks







- **Topology is more cleaner as we increase $\not\!\!E_T$ (transverse momentum of the Z^0).**
- **The correct identification of the events require to reconstruct two jets from the Higgs decay.**
- **The analysis made use of the experience with $\not\!\!E_T$ and b-jets acquired in the gluino analysis.**

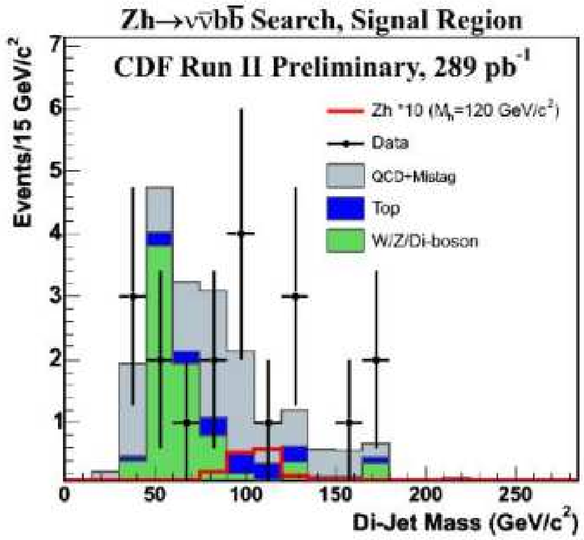
$ZH \rightarrow \nu\nu bb$ (II)

- **Preliminary results presented at EPS-2005 (last July) using 289 pb^{-1}**

$\longrightarrow$ **Selection and limit extraction no completely optimized.**

$\longrightarrow$ **The goal during this first pass was to understand control regions and sample content.**

Region	Expected (bg)	Obs. (0.16 for signal)
$\not\!\!E_T$ small (QCD)	12.4 ± 4.9	16
With a lepton (EWK)	38.3 ± 9.7	47
Signal region	19.7 ± 5.2	19



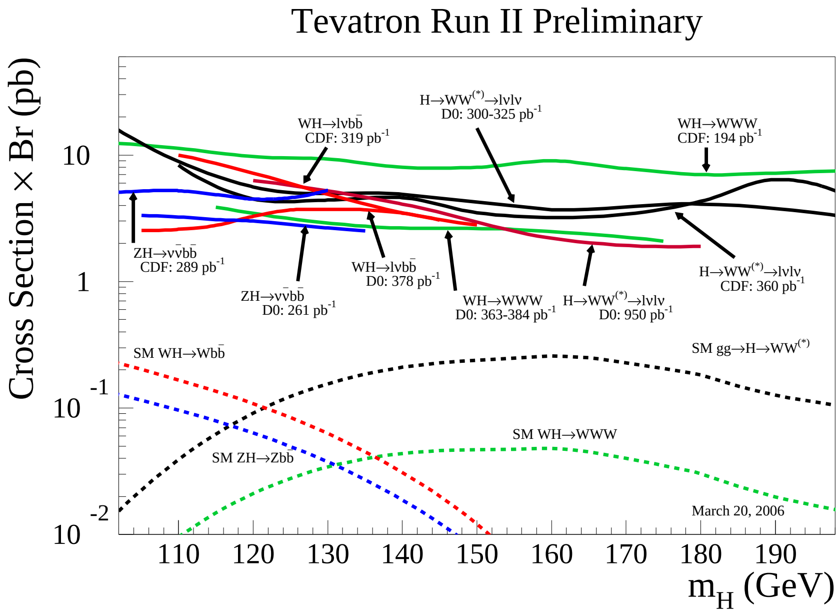
Analysis require several improvements to be competitive

$\Rightarrow$ **Addition of the WH when lepton is missing to increase the acceptance.**

$\Rightarrow$ **Use of better experimental techniques to reduce background (Neural-Network or similar approaches).**

$\Rightarrow$ **Improve resolution, especially in the dijet mass.**

$\Rightarrow$ ...



The plan is to study and include the improvements in the next generation of the analysis, in order to be able to get the best sensititivity with the Run II data

Conclusions and outlook

- Presented a summary of the analyses on searches based on the $\not\!\!E_T$ + b-jet(s) sample from the CDF data.
- Very atractive selection for new Physics (and also SM studies)
- Developed on analysis techniques for this kind of analysis are almost finished.
- Still a few challenges for the remaining Run II:

  $\Rightarrow$ Reconstruction of $\not\!\!E_T$ in the trigger to select events

  $\Rightarrow$ Reconstruction of events with several $p\overline{p}$ collisions (pile-up).

  $\Rightarrow$ b-tagging also affected by high occupancy in tracking.

- Search of direct s-bottom production still on-going.
- S-bottom from gluino production very sensitive (plan to redo it with 1 fb^{-1})
- The search for the Higgs has big potential in this channel. However, several improvements are still needed

Lots to do to get the most out of the $\not\!\!E_T + b\bar{b}$ sample