Search for Low Mass Higgs Boson at the Tevatron

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On behalf of the

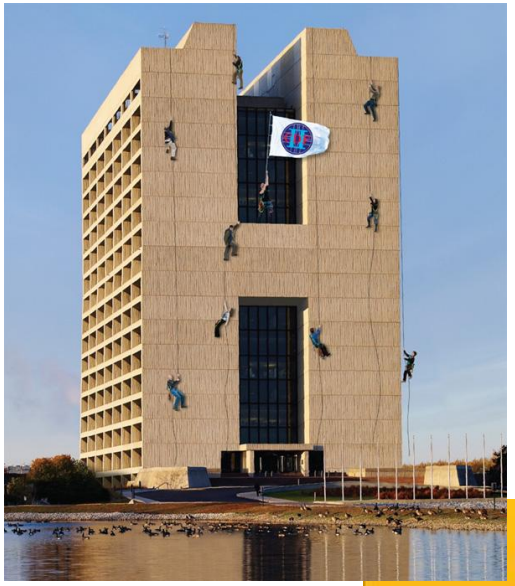
CDF and DØ collaborations

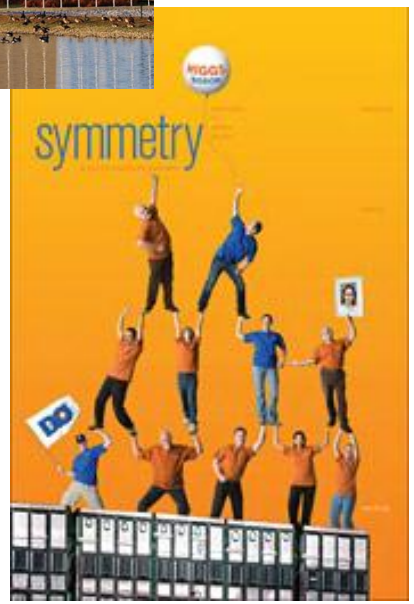
46th Rencontres de Moriond (Electroweak)

La Thuile, 3/14/2011

Outline

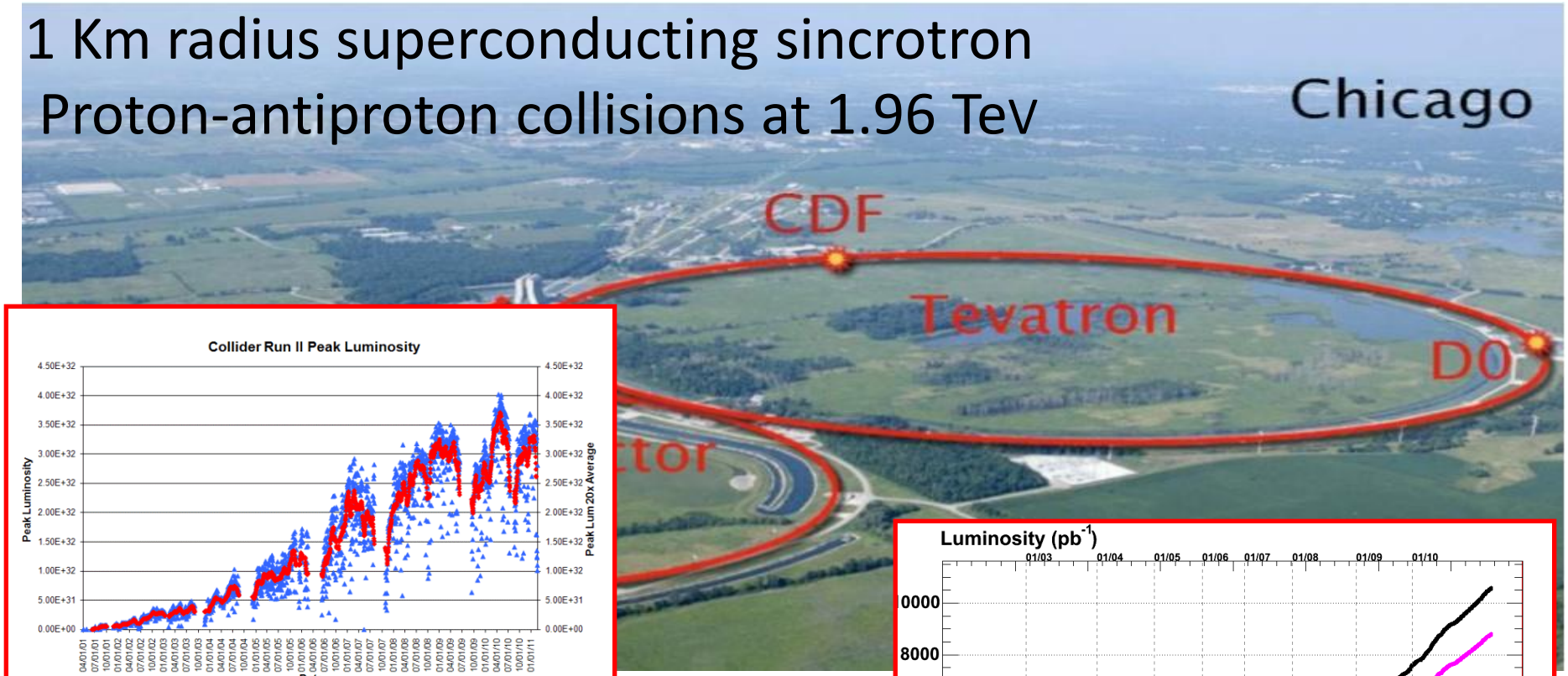
- The Tevatron collider
- The CDF and D0 detectors
- Low Mass Higgs searches at Tevatron: State of the Art
- Strategies for improvements
- Latest results and prospects for the near future

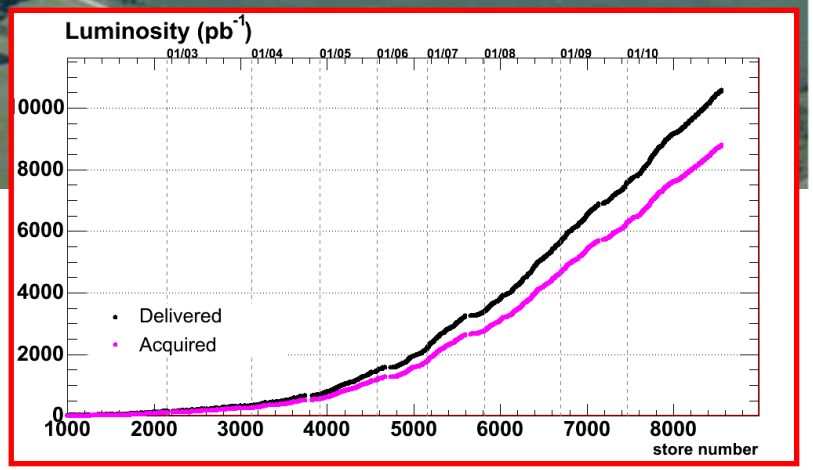




The TeVatron

1 Km radius superconducting sincrotron
Proton-antiproton collisions at 1.96 Tev



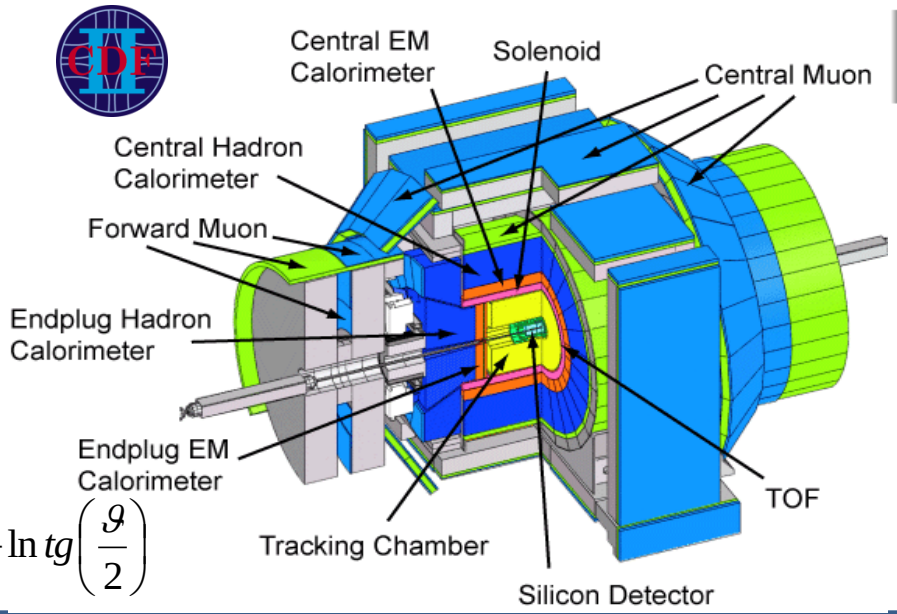


-peak luminosity 4 X 10^{32} $cm^{-2}s^{-1}$;
-Delivering ~60 pb^{-1}/week
-Over 10 fb^{-1} delivered per experiment

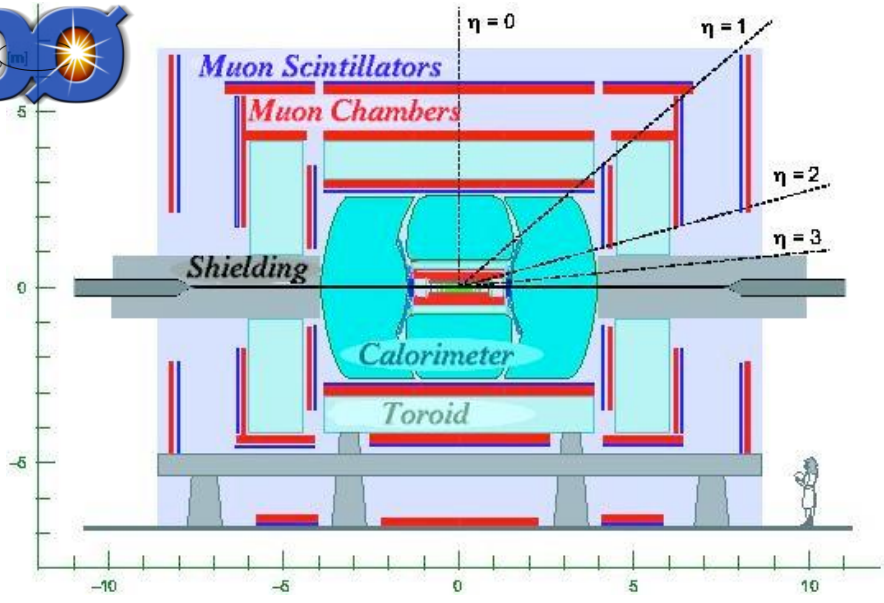
CDF and D0 detectors

General purpose detectors, axial and forward-backward symmetric

	CDF		D0	
High precision tracking	Silicon Drift cell	$\|\eta\|<2\text{-}2.5$ $\|\eta\|<1.1$	Silicon Fiber	$\|\eta\|<3$ $\|\eta\|<1.7$
EM/HAD calorimeters	Scintillators	$\|\eta\|<3.6$	LAr/DU	$\|\eta\|<4$
Muon chambers	Drift/scint	$\|\eta\|<1.5$	Drift/scint	$\|\eta\|<2.0$

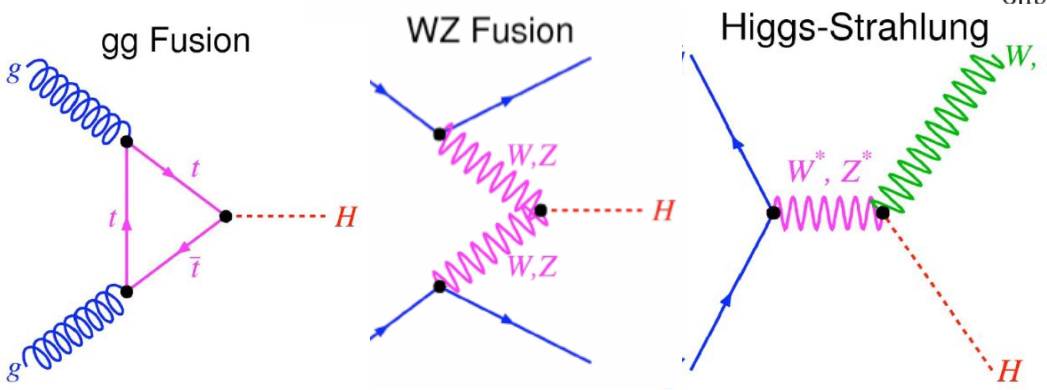


$$\eta = -\ln tg\left(\frac{\vartheta}{2}\right)$$

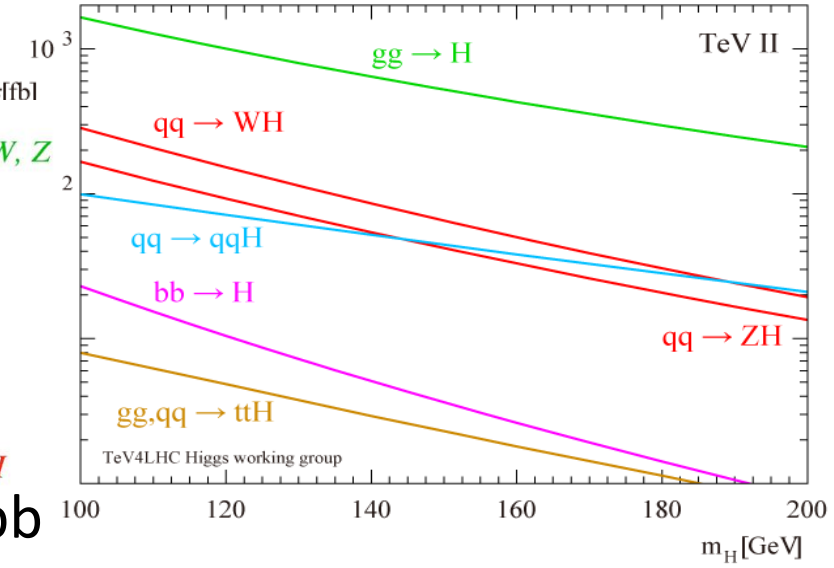


SM Higgs production and decay

Primary production modes:



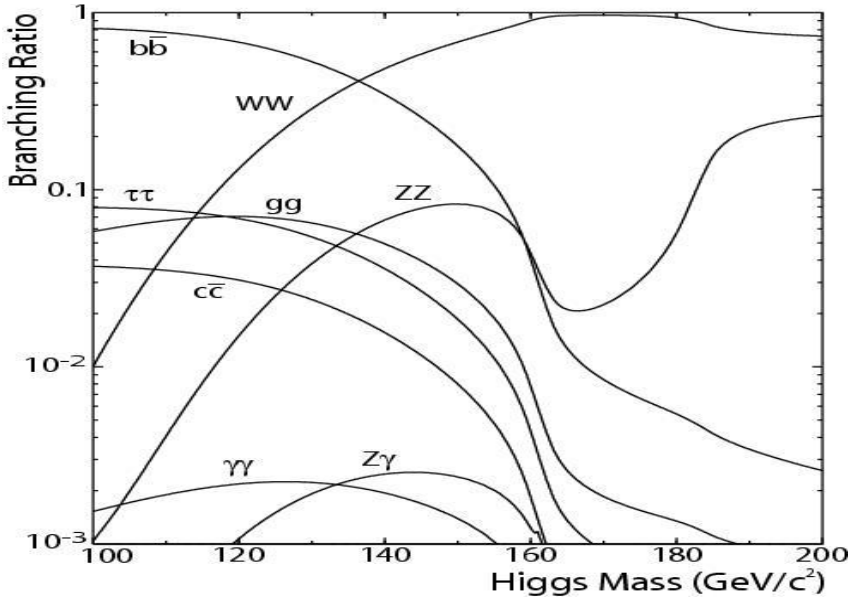
1.8 – 0.2 pb 0.1 – 0.02 pb 0.5 – 0.03 pb



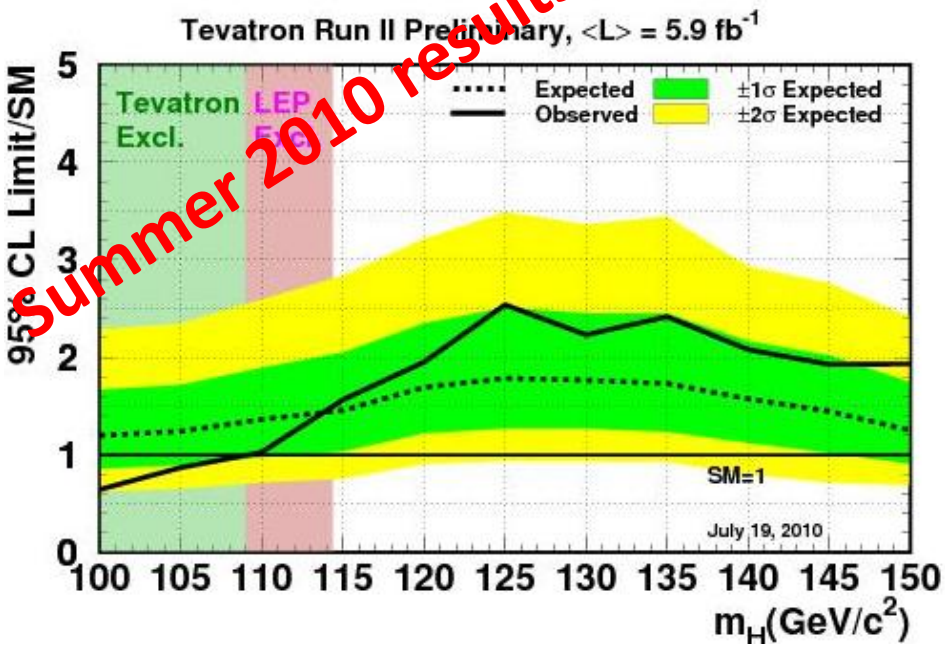
Principal decay modes:

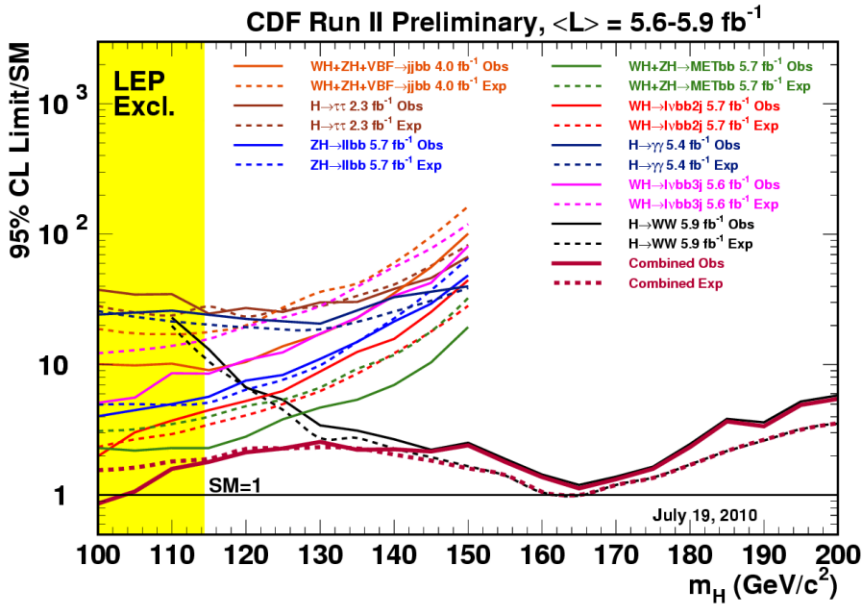
H→bb for M_H<135 GeV/c^2

H → WW* for M_H>135 GeV/c^2



Low Mass Higgs searches: State of the Art





- Combined CDF and D0 searches
- Bayesian and modified frequentist methods for the limit calculation
- **SM Higgs excluded between 100 and 109 GeV/c^2 at 95% C.L.**
- **95% C.L. Limit: 1.45 (1.58) X SM Expected (observed) @ 115 GeV/c^2**

Low Mass Higgs searches: State of the Art

Analyses included in the Summer 2010 Tevatron limit combination

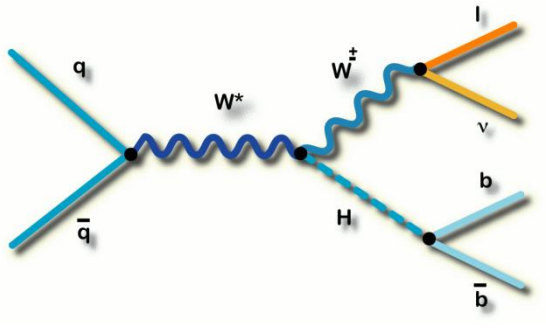
	CDF		D0	
	Lum	Exp. Limit(115 GeV/c2)	Lum	Exp. Limit (115 GeV/c2)
WH→lvbb	5.7	**3.5**	5.3	**4.8**
ZH→vvbb	5.7	**4.0**	5.2-6.4	**4.2**
ZH→llbb	5.7	**5.5**	4.2-6.2	**5.7**
VH/VBF→bb jet jet	4.0	**17.8**		
VBF/VH/ggH→ττ+jets	2.3	**24.5**	4.9	**15.9**
H→γγ	4.2	**20.8**	4.2	**18.5**
ttH→ttbb			2.1	**45.3**

Covered up to 6 fb^{-1} of data

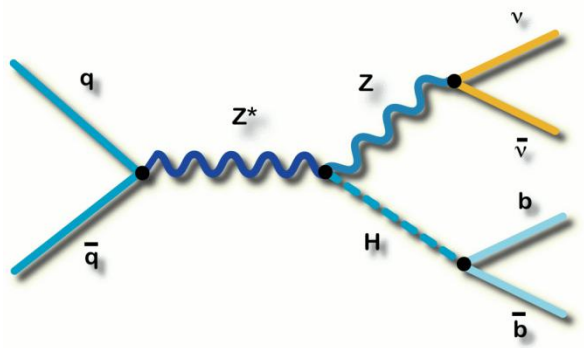
Many efforts ongoing to extend data luminosity and improve overall sensitivity

Main channels: associated production

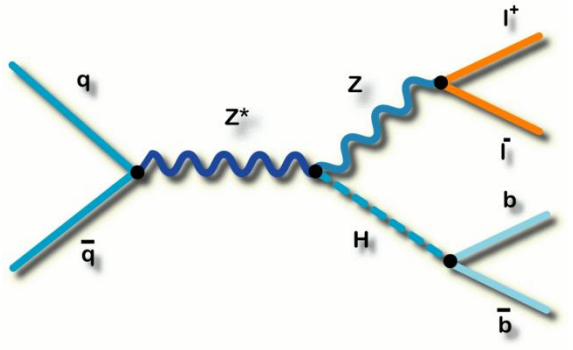
3 dominant final states with comparable sensitivities



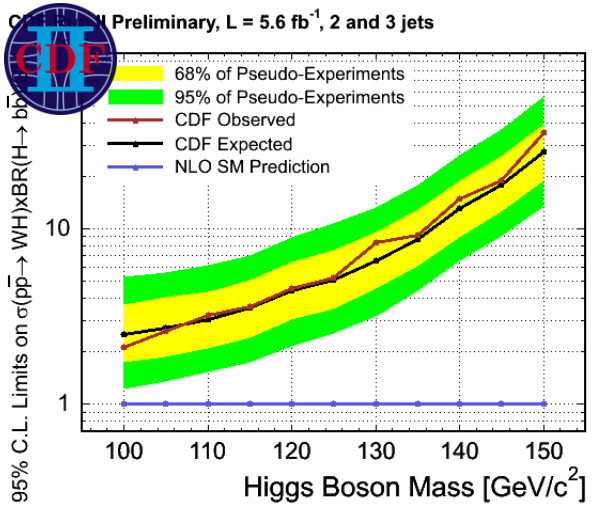
$WH \rightarrow \nu lbb$

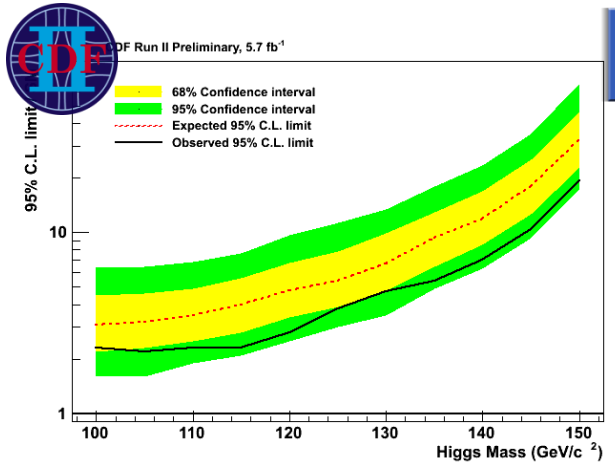


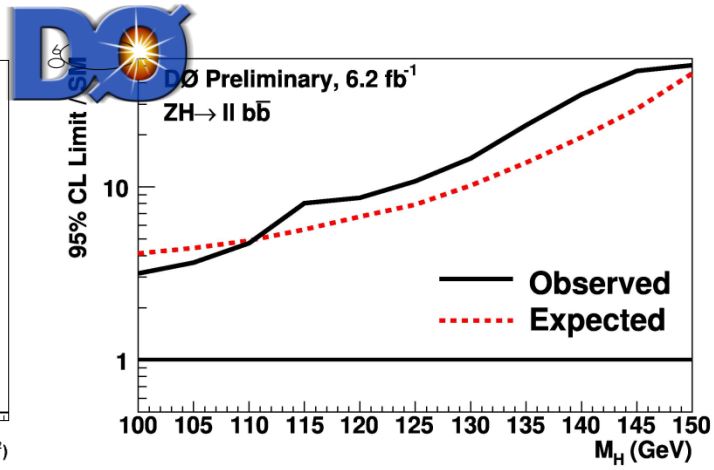
$ZH \rightarrow \nu\nu bb$



$ZH \rightarrow llbb$





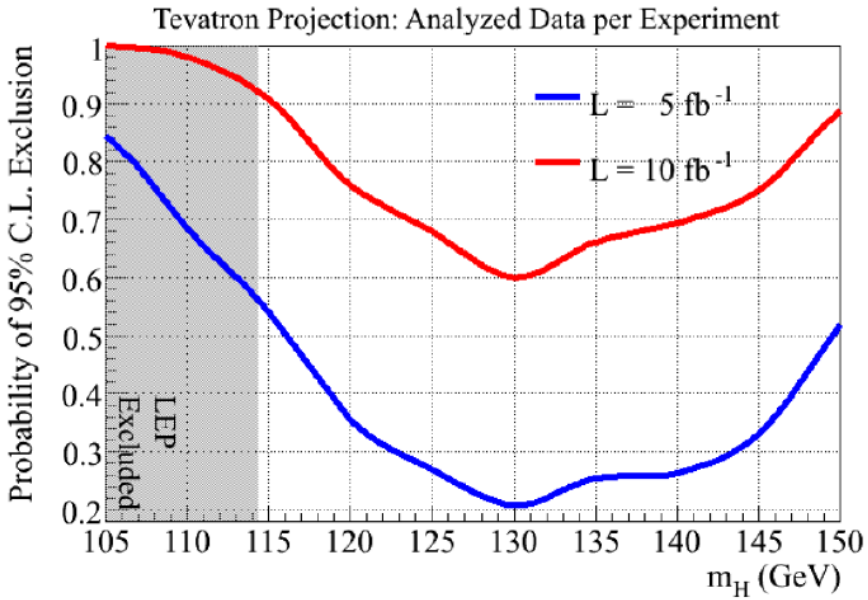


TeVatron Prospects

Tevatron will run up to September 2011:

- about 12 fb^{-1} of data delivered per experiment
- about 10 fb^{-1} of data available for the analyses

-Tevatron could exclude the Higgs in the entire mass range and have a chance for 3 sigma evidence:

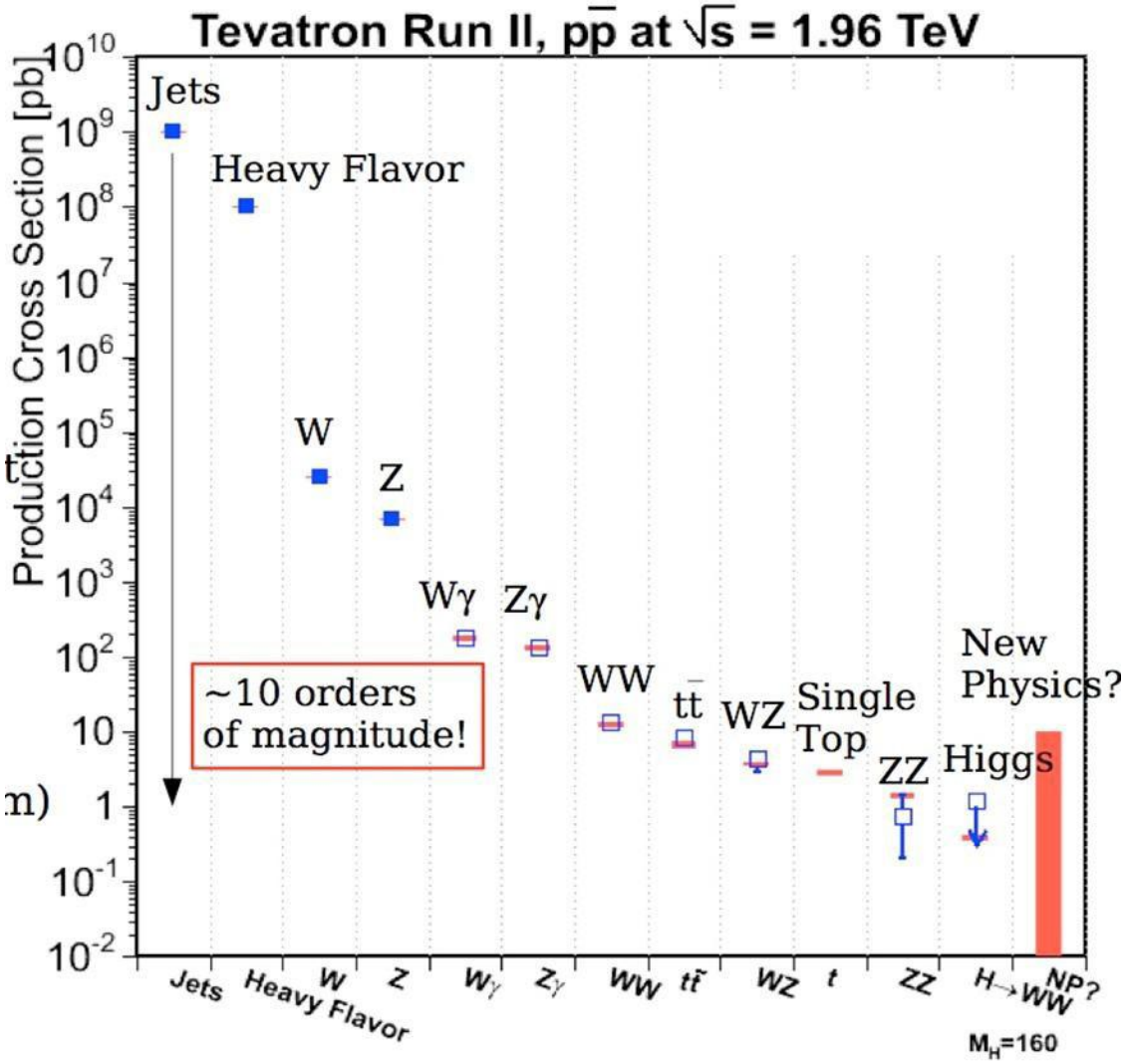


Doubling the statistics is not enough: these results are achievable only with search improvements

The challenge

Higgs searches:

Look for a very tiny signal, with backgrounds several order of magnitude larger



Strategies for search improvements

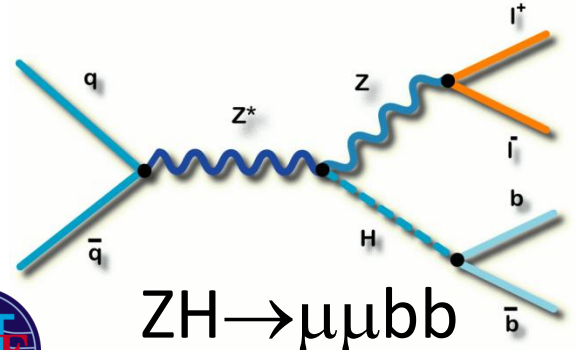
Maximize the signal acceptance

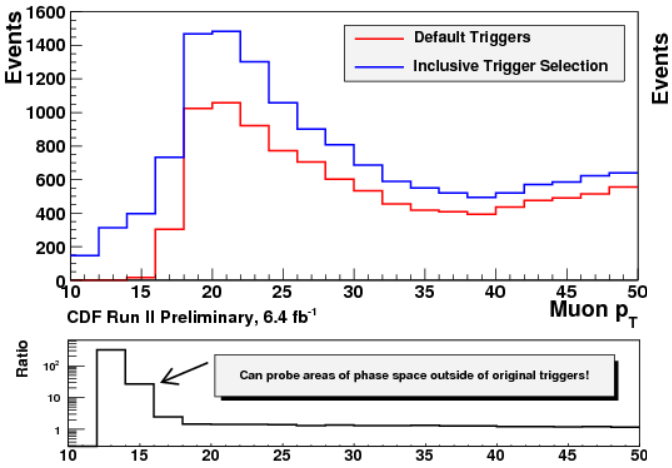
-Including new triggers

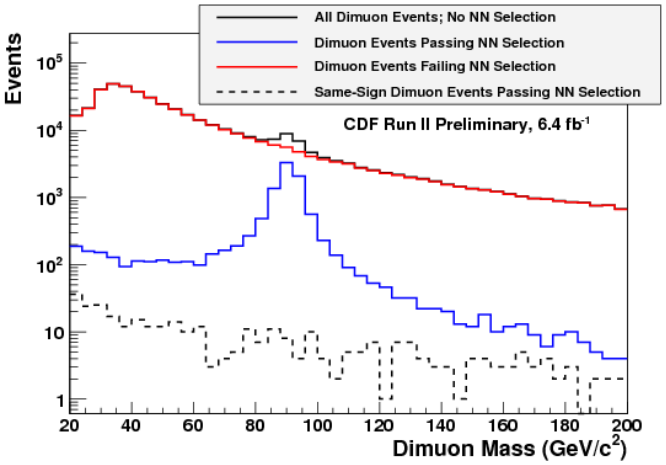
-Improving lepton ID: loose pT

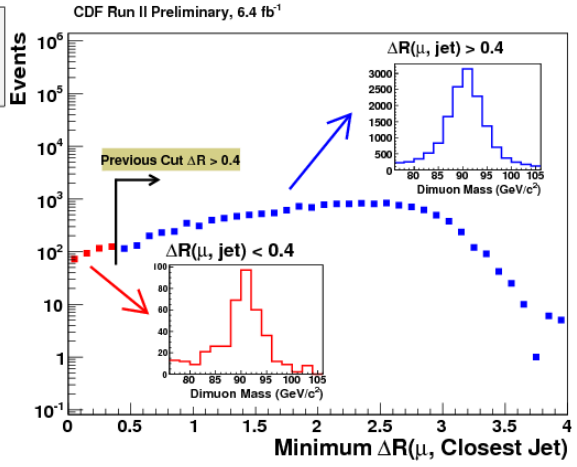
multivariate selections

-Releasing kinematic cuts









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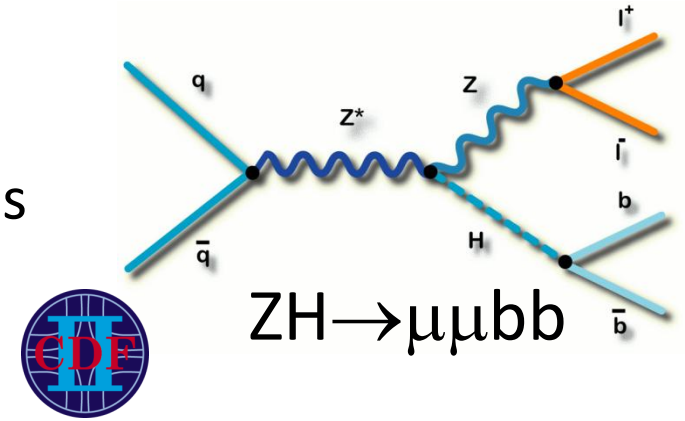
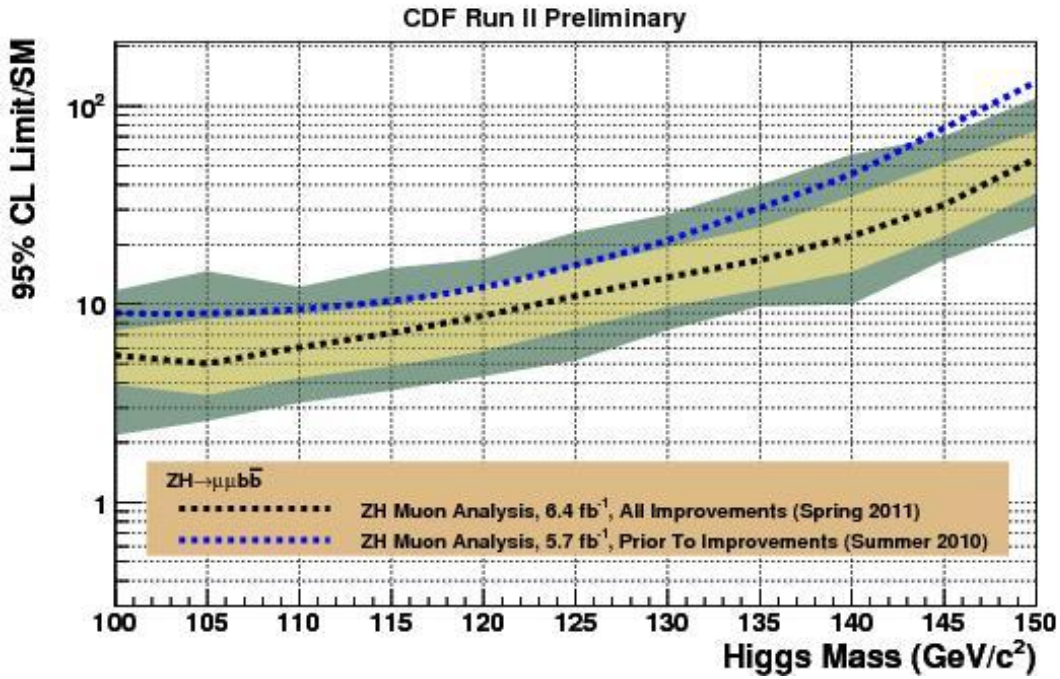




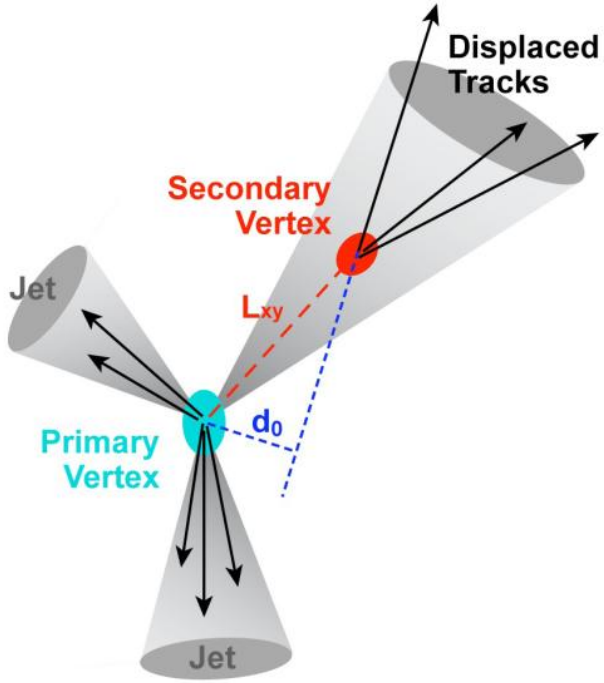
Sensitivity improvements:
from 30% up to 60%

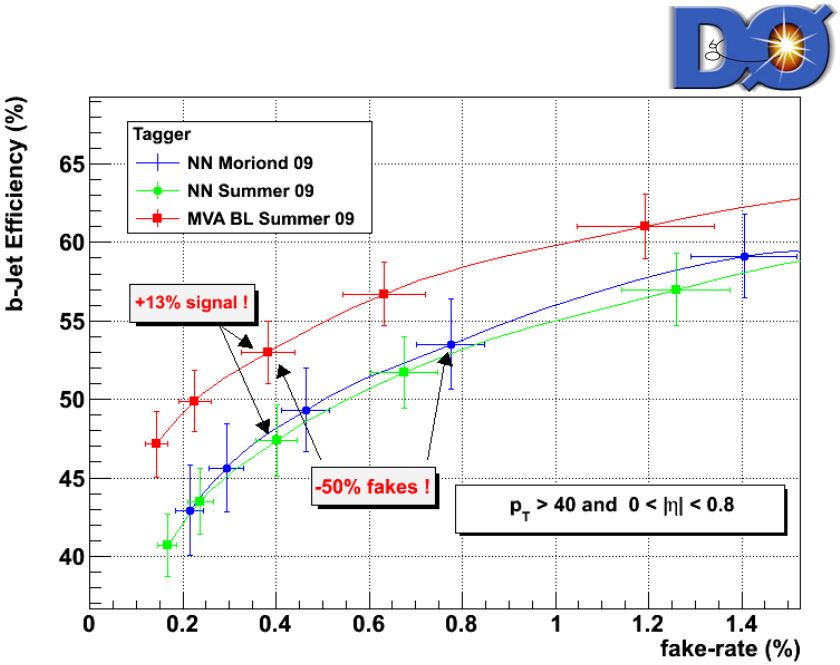
Exp.Limit @115 GeV/c^2
before updates: 10.4
after updates: 7.1

Strategies for search improvements

Reduce W/Z+jets background with b-quark jets identification

Exploit the long lifetime of B-hadrons: jets with displaced vertexes from the interaction point

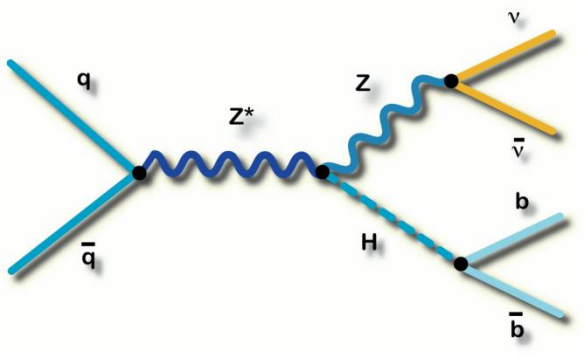




- New tagging algorithms
- Different training techniques
- Optimized operating points

Strategies for search improvements

Reduce W/Z+jets background with b-quark jets identification

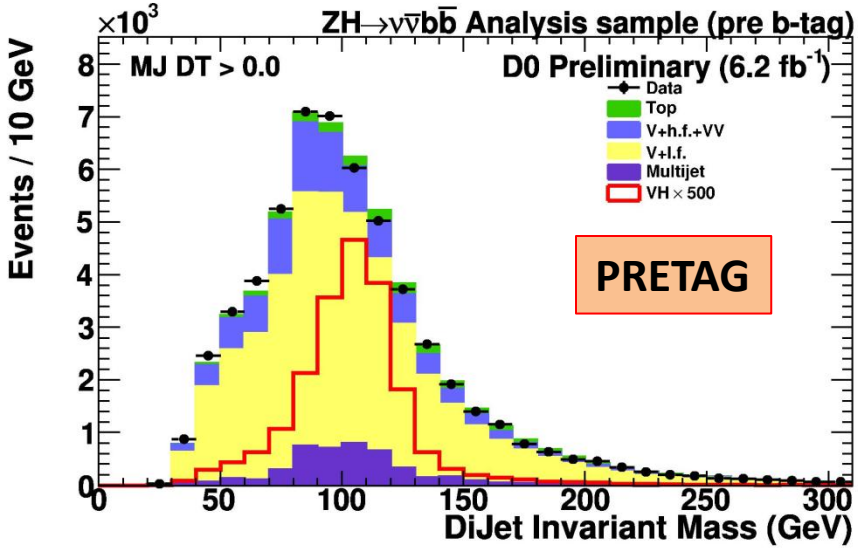


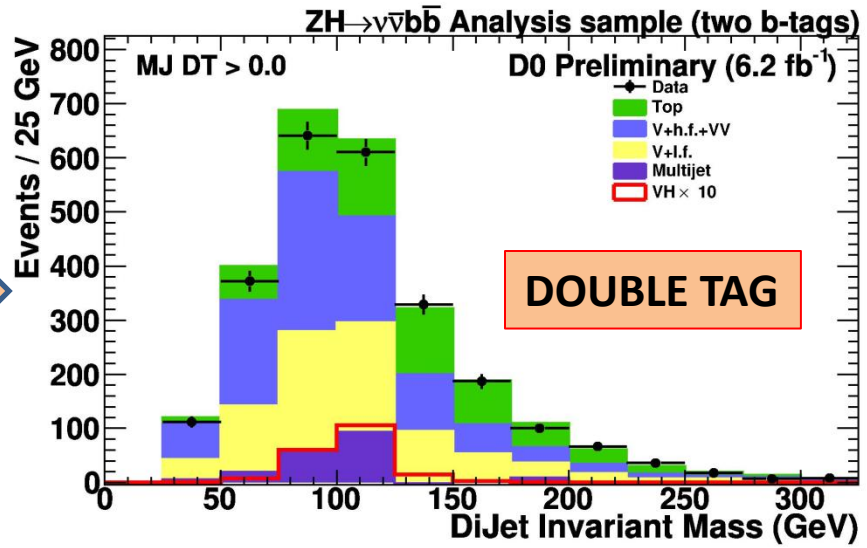
$ZH \rightarrow \nu\nu bb$

NN replaced by a new MVA tagger

Pre-tag **S/B ~ 10^{-4}**

Two b-tagged jets: **S/B ~ 10^{-2}**



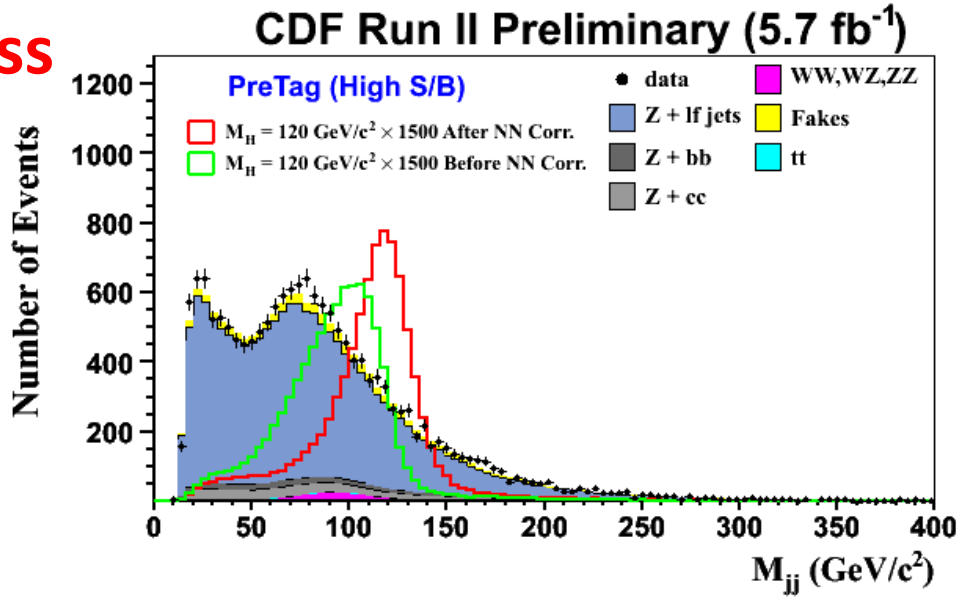


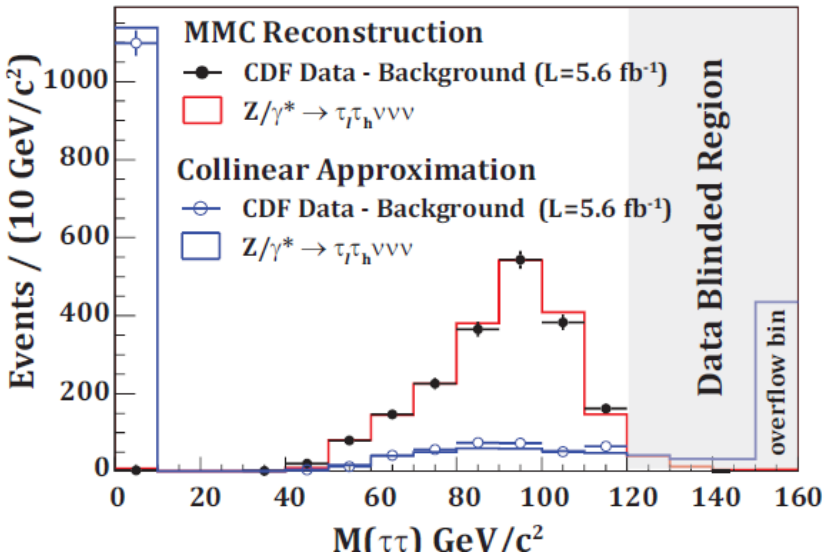
Strategies for search improvements

Improving dijet invariant mass

Implement a **Neural Network** and exploit all tracking and calorimeter information

~15% of resolution improvement





Improving di-tau invariant mass

- Difficult, because of the presence of neutrinos

-Recovering the information from missing energy

- Need to separate H→ττ from Z →ττ resonance peak

Strategies for search improvements

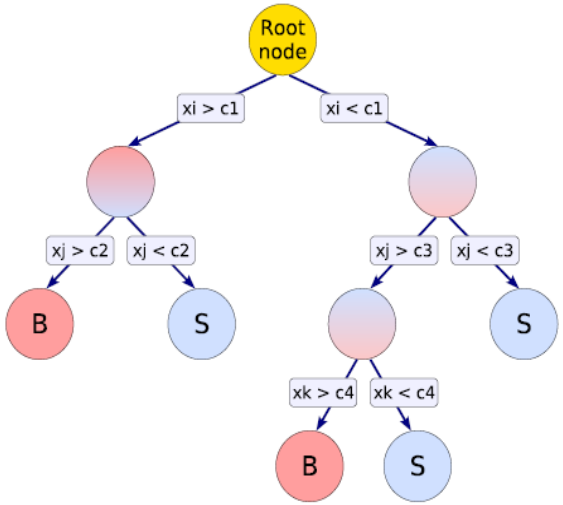
Multivariate techniques: Improve signal vs bkg separation by combining different kinematic variables

MATRIX ELEMENT METHOD

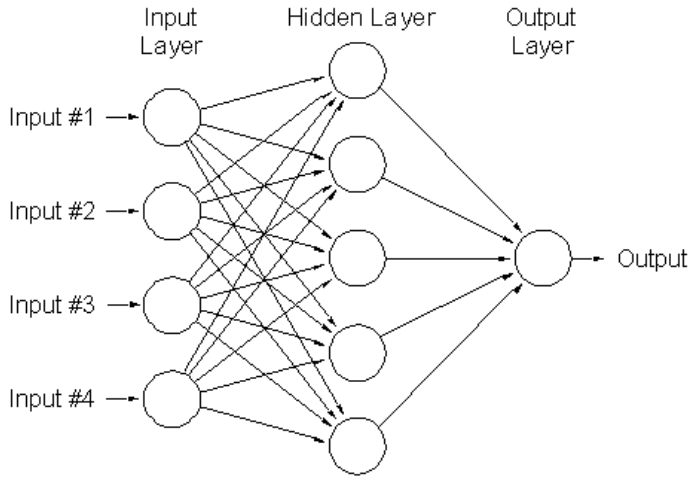
$$P(p_l, p_{jet}) = \frac{1}{\sigma}\int d\rho_{jet}\, dp_v \sum \phi_4 \,|M(p_i)^2|\, \frac{f(q_1)\,f(q_2)}{|q_1||q_2|}\, W_{jet}(E_{parton}, E_{jet})$$

ME **PDFs** **Transfer functions**

BOOSTED DECISION TREES

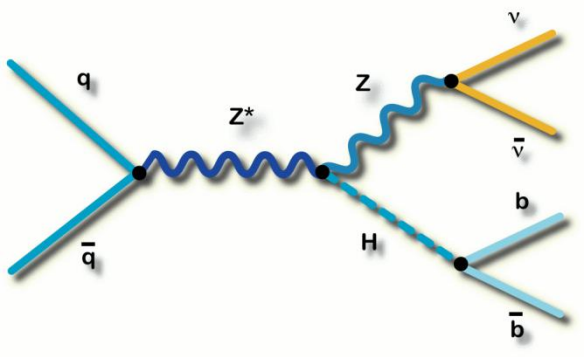


NEURAL NETWORKS

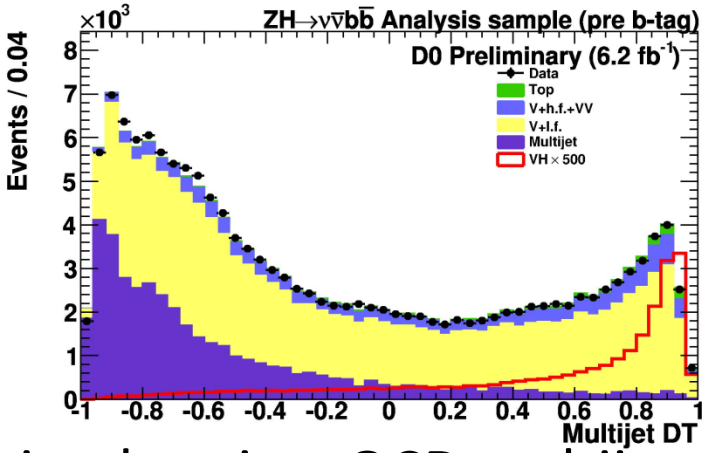


Strategies for search improvements

Multivariate techniques: Improve signal vs bkg separation by combining different kinematic variables

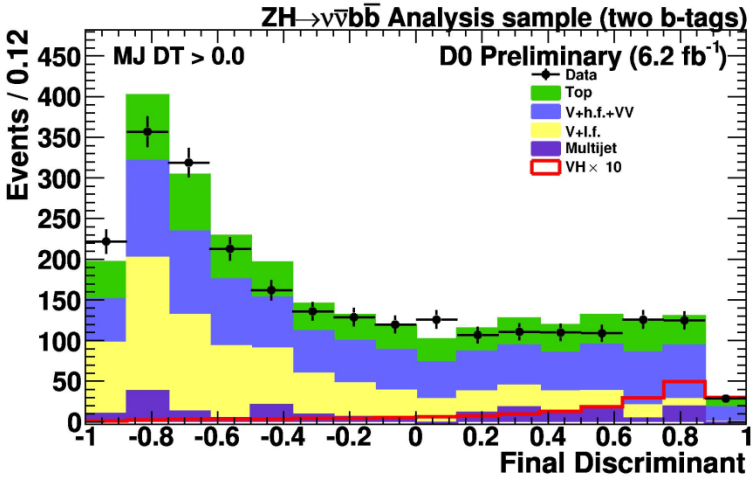


ZH→νν̄bb̄



BDT trained against QCD multijet

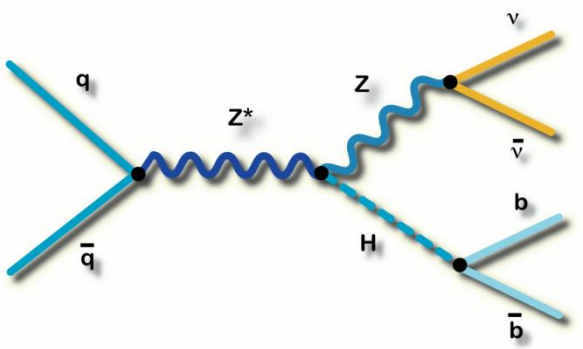
- cut on the output: keep>70% signal
  remove>90% QCD



Final discriminant

- After loosening b-tagging operating points use NN b-tagging output as a new BDT input variable

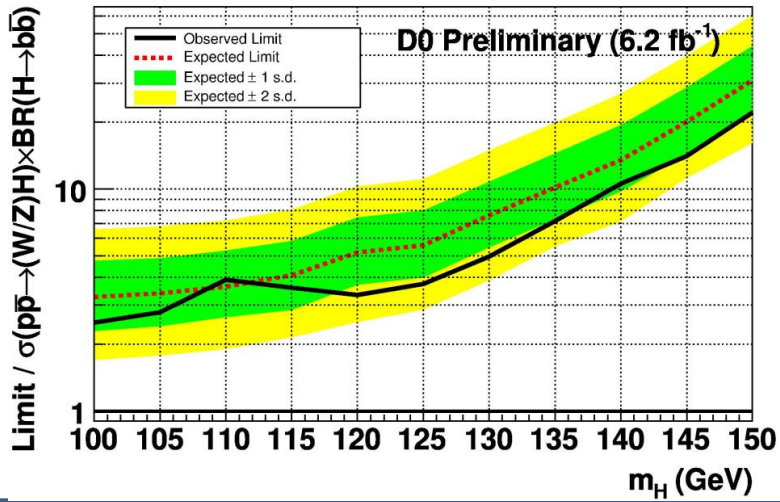
Strategies for search improvements



$ZH \rightarrow \nu\nu bb$

-Looser b-tagging selection: acceptance increase
-Optimized multivariate techniques: more statistics for training, new input variables

15% sensitivity improvement



Exp.(obs)Limit @115 GeV/c^2: 4.0(3.4) x SM

Strategies for search improvements

Including as many Higgs channels as possible:

- A lot of help in increasing the sensitivity can come from secondary channels, complementary to $H \rightarrow bb$
- Most of the contribution can be provided at the intermediate masses, around 135 GeV/c^2

Latest CDF and D0 results are:

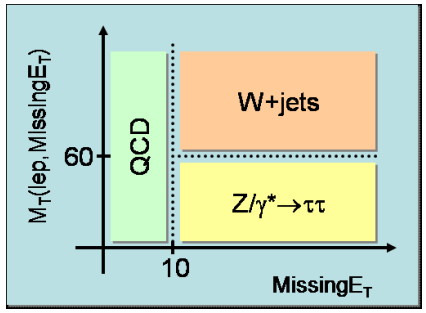
	Lum	Exp. Limit(115 GeV/c^2)	Obs. Limit(115 GeV/c^2)
$H \rightarrow \tau\tau$+jets	6.0	15.2	14.6
$H \rightarrow \tau\tau$+jets	4.3	12.8	32.8
$H \rightarrow \gamma\gamma$	8.2	11.0	19.9

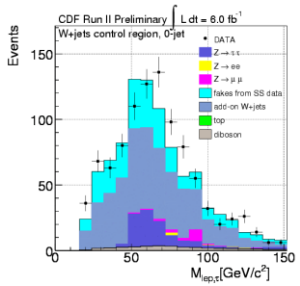
See Kathryn Tschann-Grimm's talk for $H \rightarrow \tau\tau$ D0 results

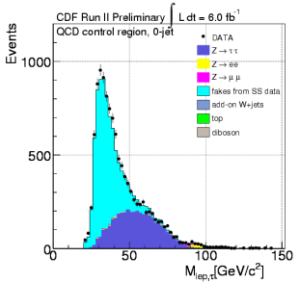
Highest luminosity Higgs search!

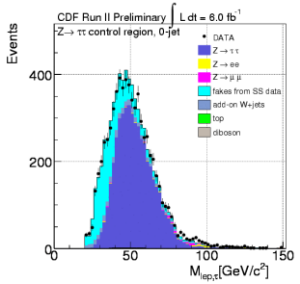
Latest results: H →ττ+jets

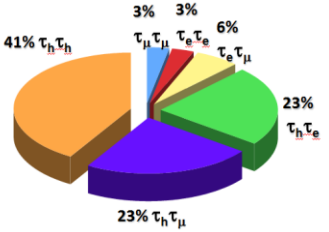
- Different channels simultaneously studied: WH/ZH/VBF and gg→H
- leptonic+hadronic tau decay considered: 46% B.R.
- 0 jet control samples:



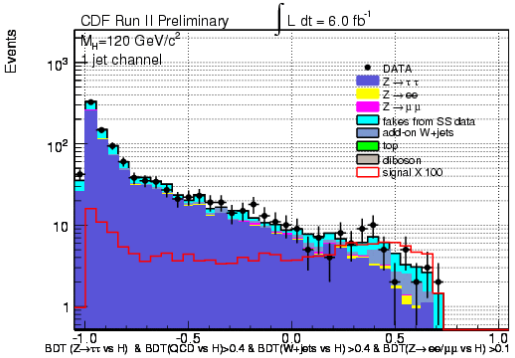




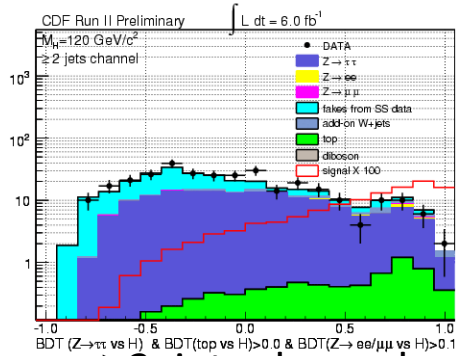




BDT discriminants

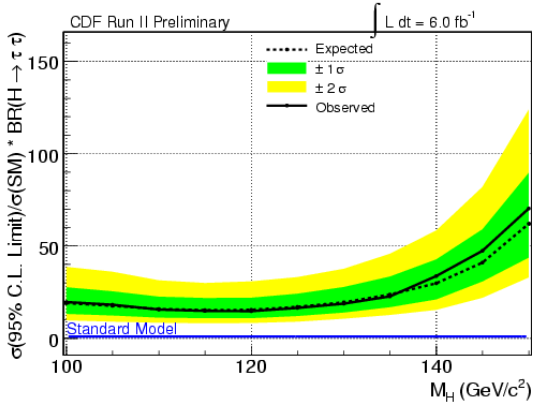


1 jet channel



≥2 jets channel

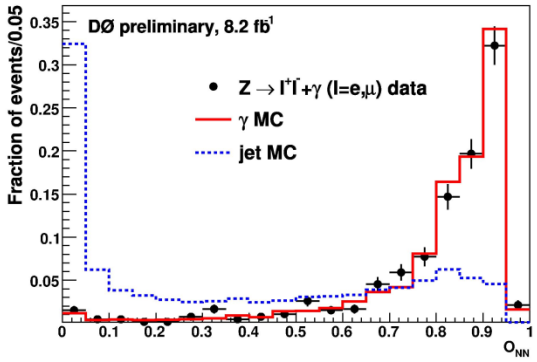
Exp.(obs)Limit @115 GeV/c^2: 15.3(14.6) X SM

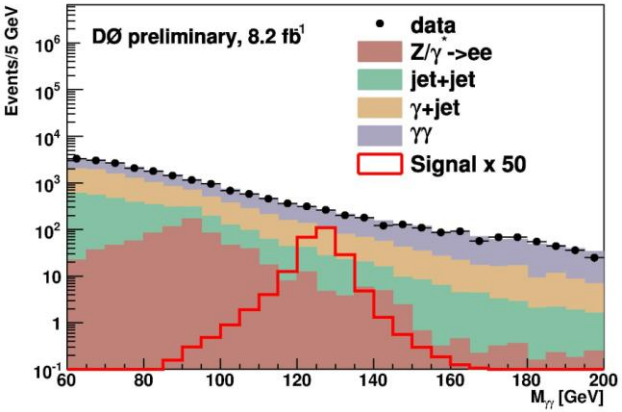


Latest results: H $\rightarrow\gamma\gamma$

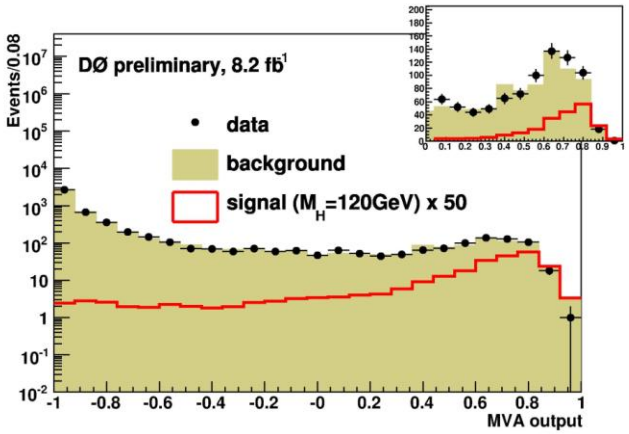
Fundamental ingredientes of the search:

- Calorimeter resolution : up to 2%
- Photon identification: improved by a NN selection

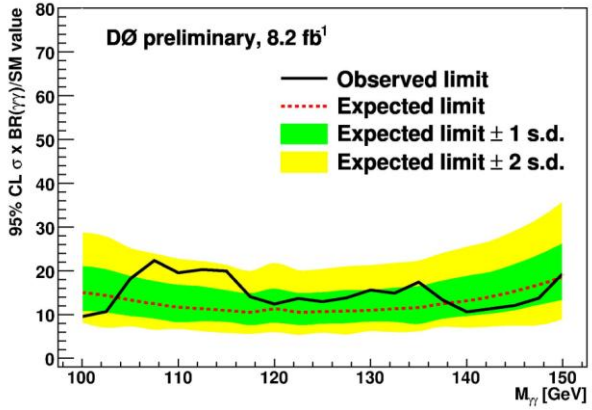




Di-photon mass



BDT discriminant



Exp.(obs)Limit @115 GeV/c^2: 11.0(19.9) x SM

Conclusions

- We have presented the current status of the Higgs Tevatron searches in the low mass region

- We have shown the ongoing efforts to increase the analysis' sensitivity

- Current combined expected limit is 1.45 x S.M. @ 115 GeV/c^2, but most of the analyses could almost double their data luminosity very soon.

- We project that the improvements in the search techniques will potentially allow to be sensitive to the Higgs signal across the entire allowed mass range

- Stay tuned with next Tevatron results!