Recherche de bosons de Higgs au Tevatron Run II

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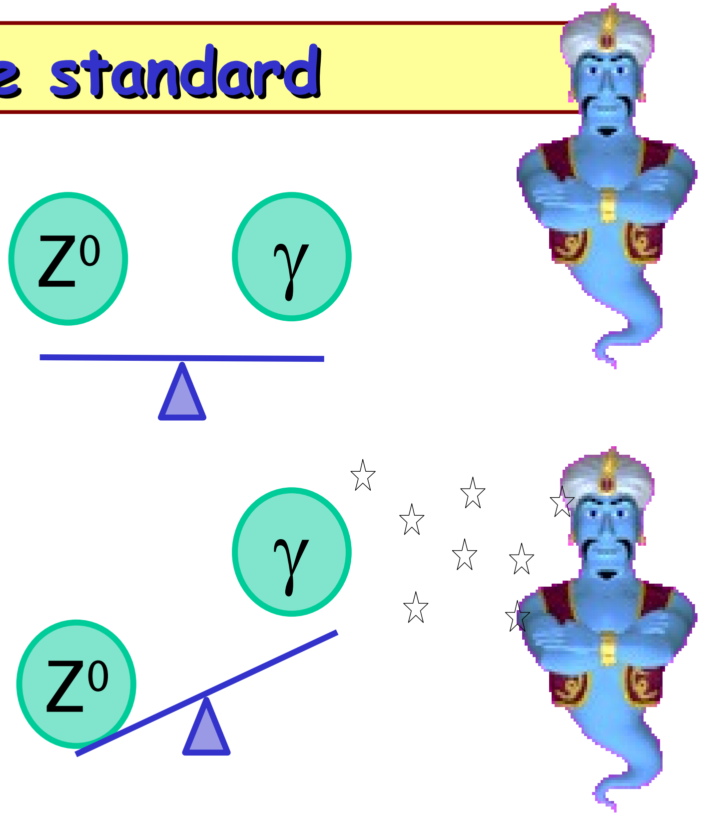
Le boson de Higgs du modèle standard

Le Modèle standard : une théorie de jauge SU(2)xU(1)

- Dans une théorie de jauge les bosons de jauge sont de masse nulle.
- Or les bosons Z et W sont massifs, l 'interaction correspondante est de courte portée : interaction faible
- Contradiction résolue grâce au mécanisme de Higgs au cours duquel la symétrie est spontanément brisée. Les bosons deviennent massifs par interaction avec le champ de Higgs qui est non nul dans le vide.



- Ce mécanisme est la clé de voûte du modèle et pourtant on attend encore les premiers signes du secteur de Higgs : la découverte du boson de Higgs

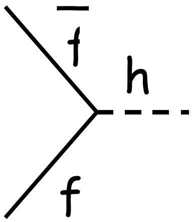
Secteur de Higgs du MS = source de problèmes théoriques.

- Renormalisation de la masse du Higgs : divergences quadratiques
- l 'échelle d 'énergie électrofaible devrait être beaucoup élevée que O(100) GeV

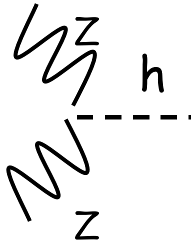
- Ce secteur de la théorie, non observé est peut-être la source de nouvelle physique…
- En particulier la supersymétrie (symétrie boson-fermion ; double le spectre de particules connues) prédit l'existence d'un secteur de Higgs étendu avec un boson léger

Couplages et Rapports d 'embranchement

- Dans le modèle standard une seule inconnue :
  - la masse du boson de Higgs.
- Les couplages sont connus
  - rapports d'embranchement connus

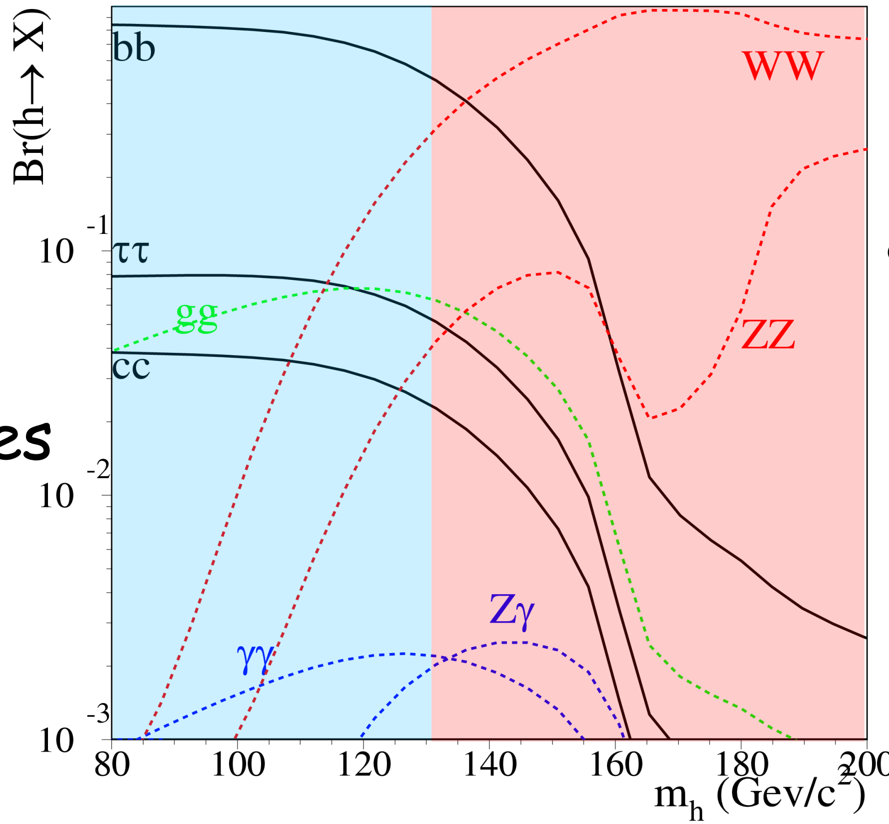


$y_f \sim g\, m_f/m_W$



$\sim g m_Z$

• m_h<130 GeV désintégrations en $b\bar{b}$ et $\tau\bar{\tau}$ dominantes

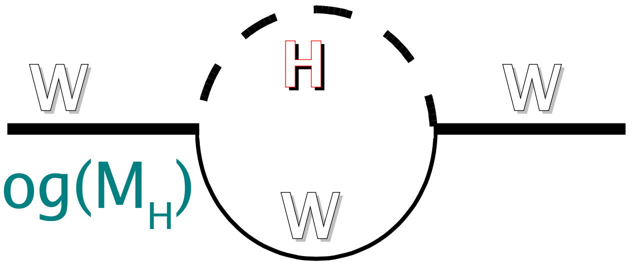


• m_h>130 GeV désintégrations en bosons de jauge dominantes

Contraintes expérimentales sur le Higgs Standard

Indirectes

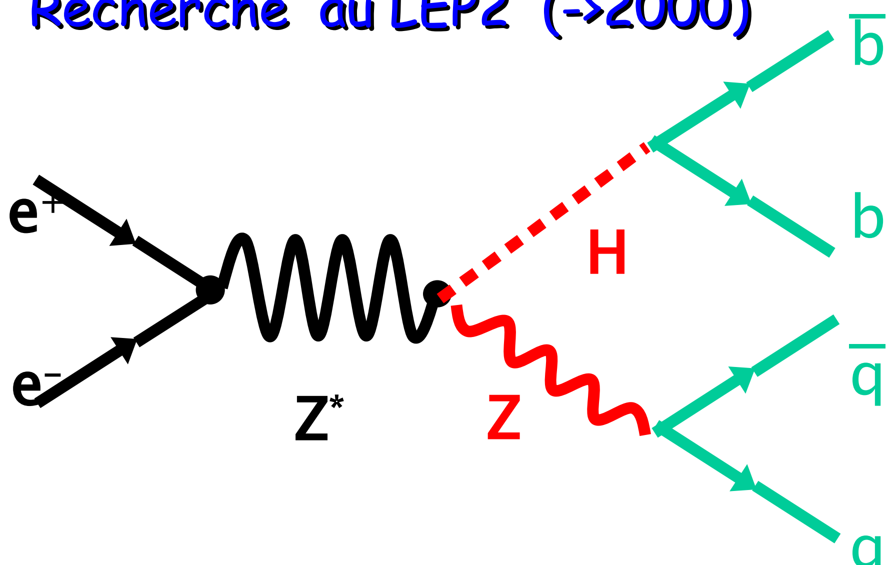
- Les corrections radiatives relient les différentes observables électrofaibles (masses, asymétries, couplages)
- Mesures de précision au LEP
- Masses du top et du W (LEP+Tevatron).

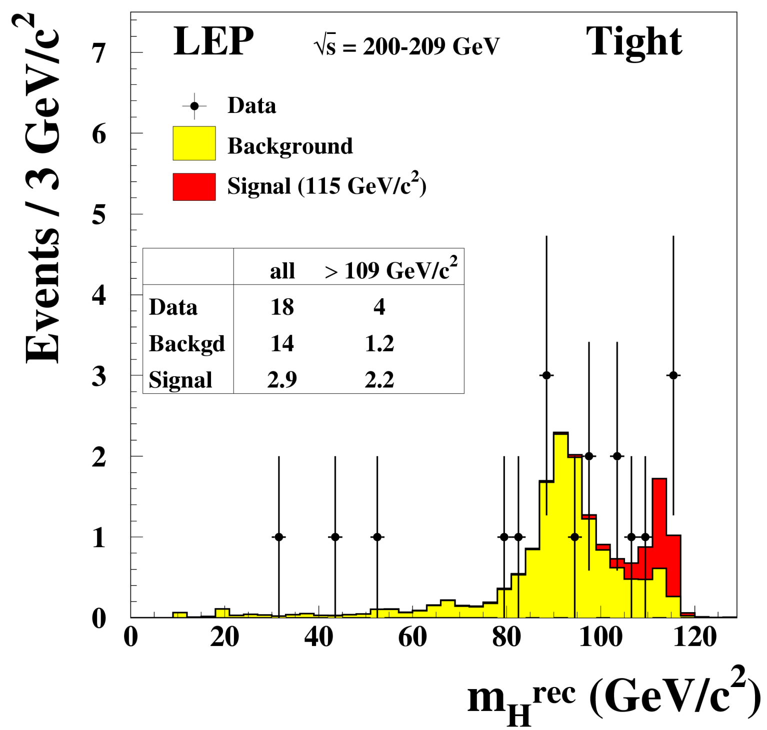


$\Delta M_W \alpha \log(M_H)$

Directes

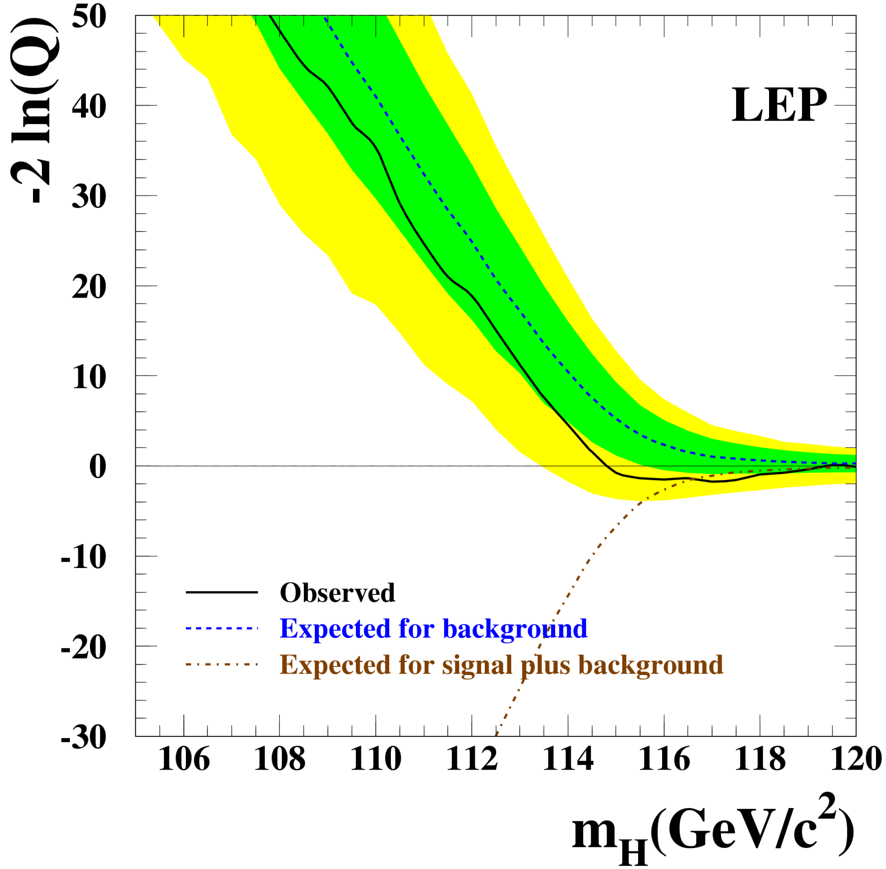
- Recherche au LEP2 (->2000)





Contraintes directes et indirectes

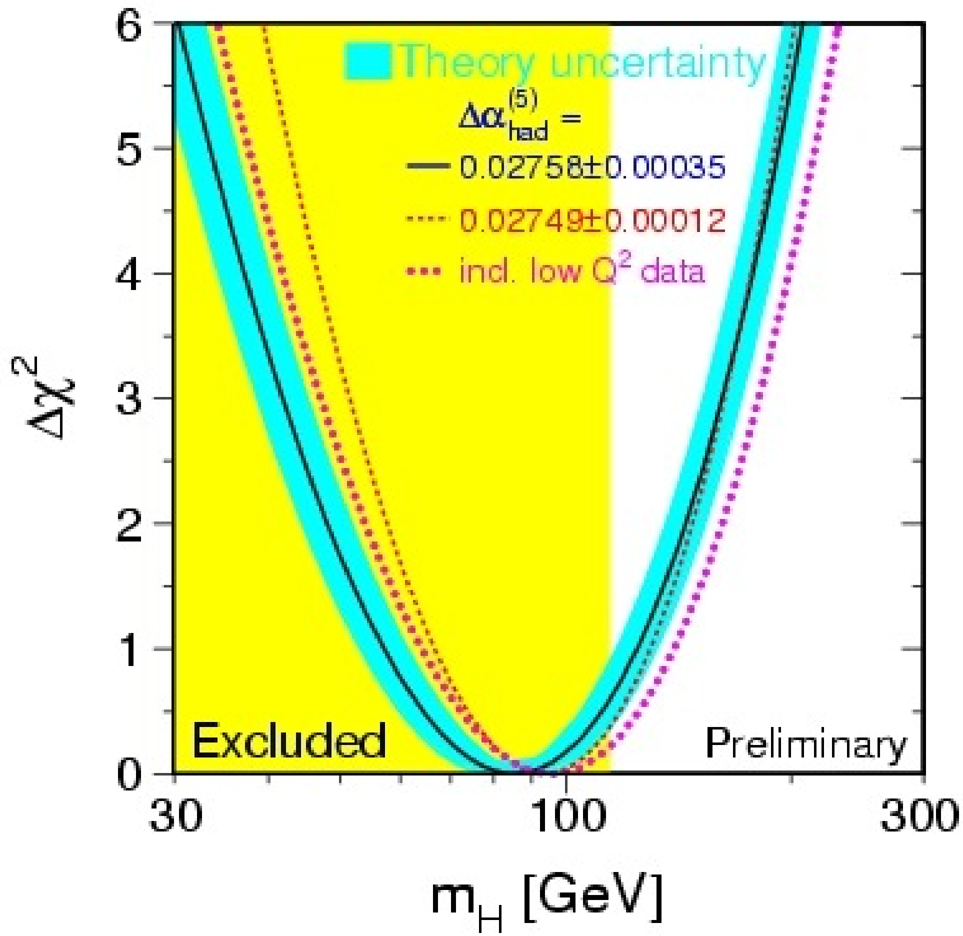
- Directes



M_H > 114.4 GeV @95%

M_H ~ [115 118] (excès 1.7σ)

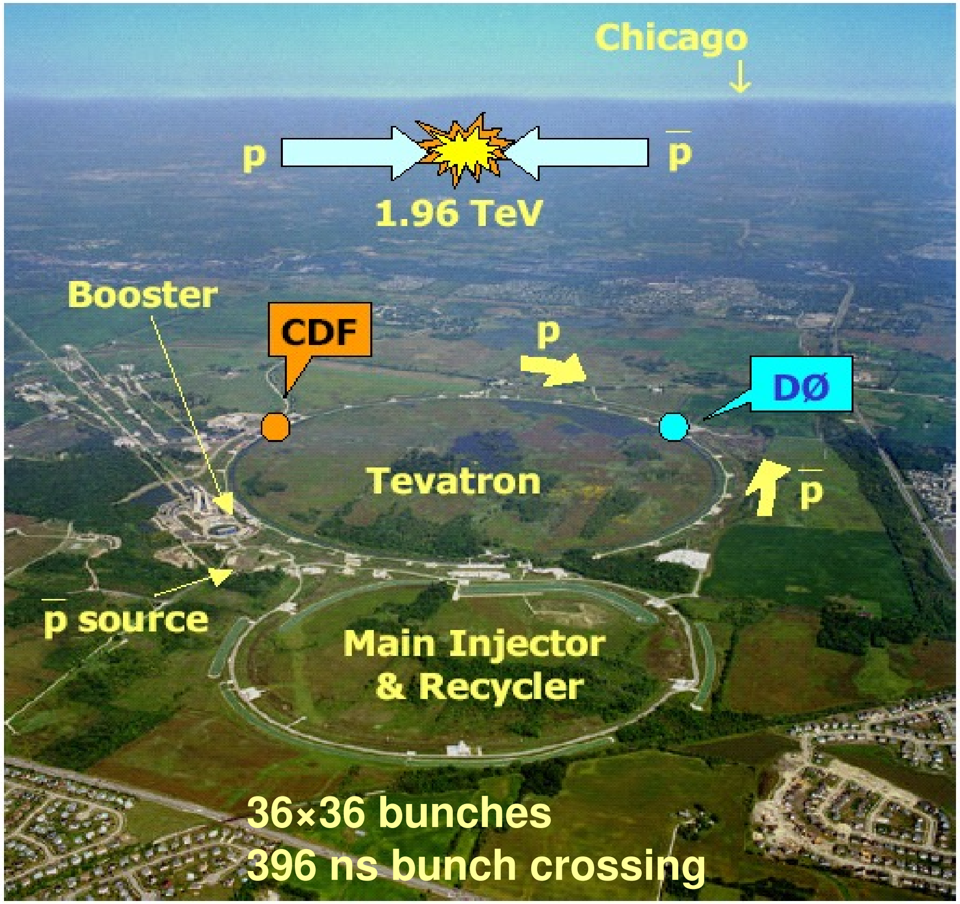
- Indirectes



$$M_H = 85^{+39}_{-28}\ \mathrm{GeV}/c^2$$

$$M_H < 166\ \mathrm{GeV}/c^2\ @\ 95\%\ C.L.$$

Tevatron

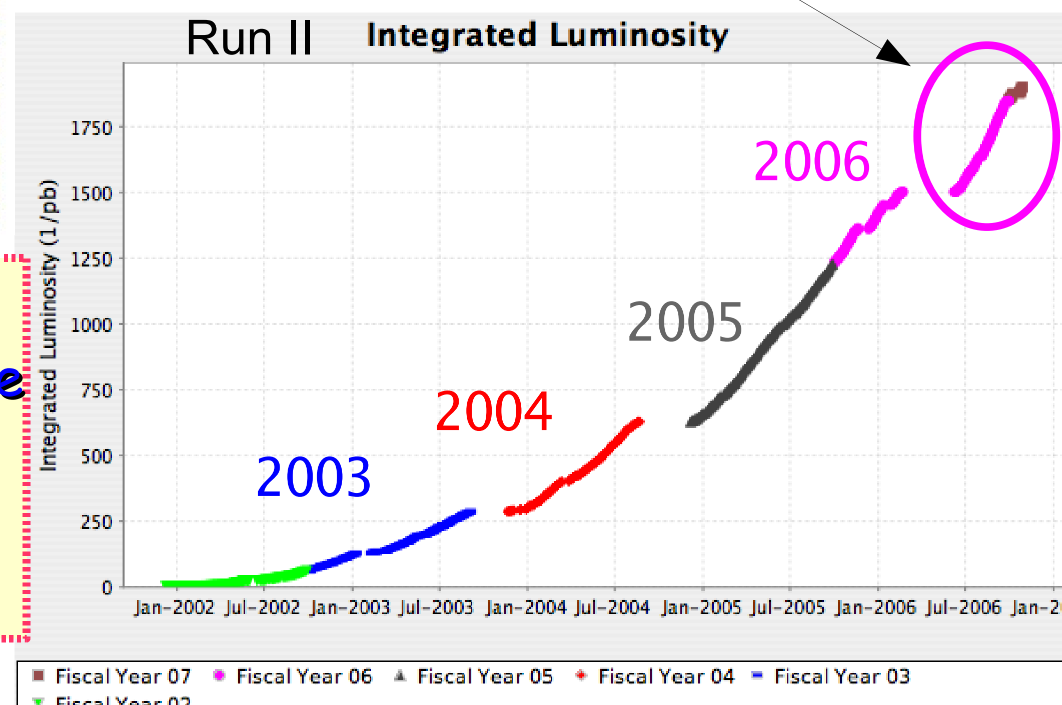


Run I (1993-1996)
~120 pb^{-1} par expérience
découverte du top
Run IIa: (2002-2006)
~1.5 fb^{-1} par expérience
(délivrée)

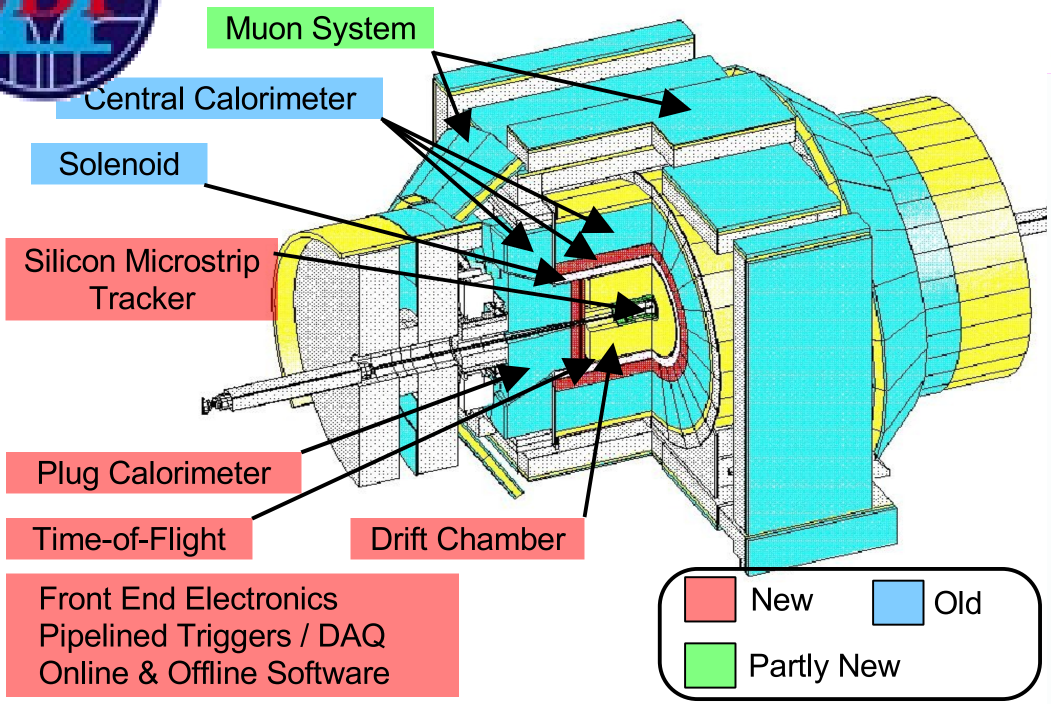
Run IIb a commencé en juin
4 à 8 fb^{-1} en 2009

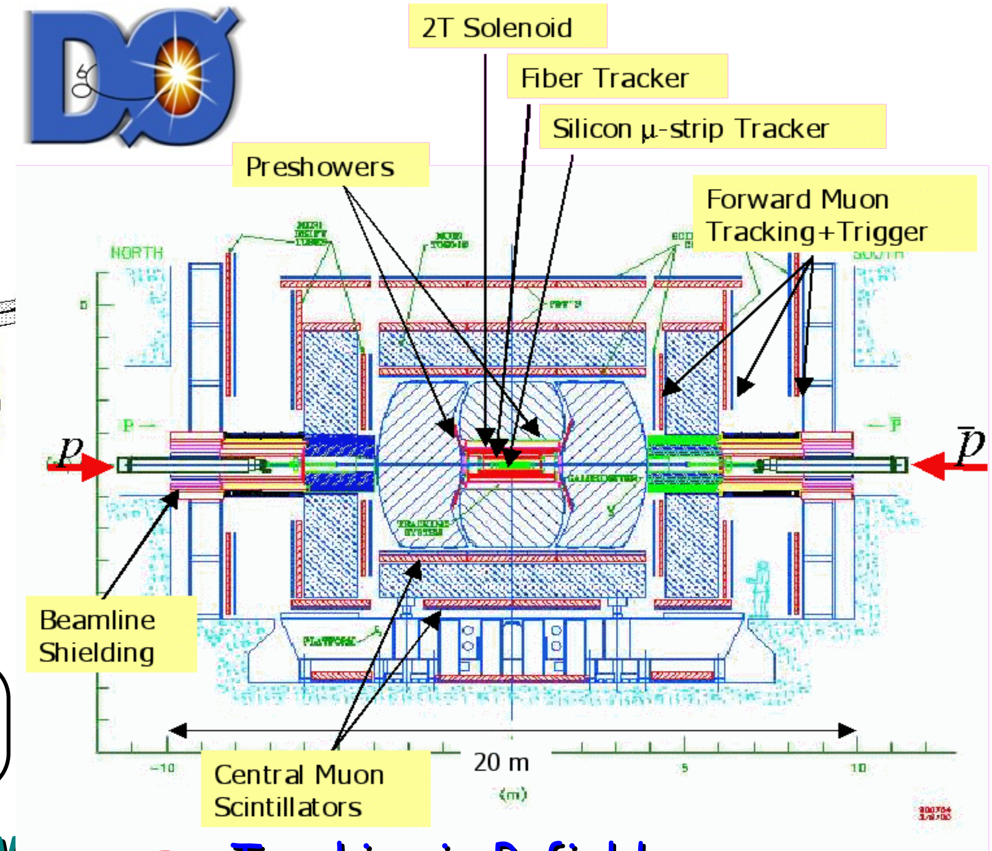
Eté 2006, ~ 1 fb^{-1}/expmt de qualité suffisante pour les analyses de physique

Toutes les analyses n'ont pas encore utilisé toute la stat disponible.



Tevatron Experiments at RunII





New
- silicon detector
- Drift chamber
- TOF PID system

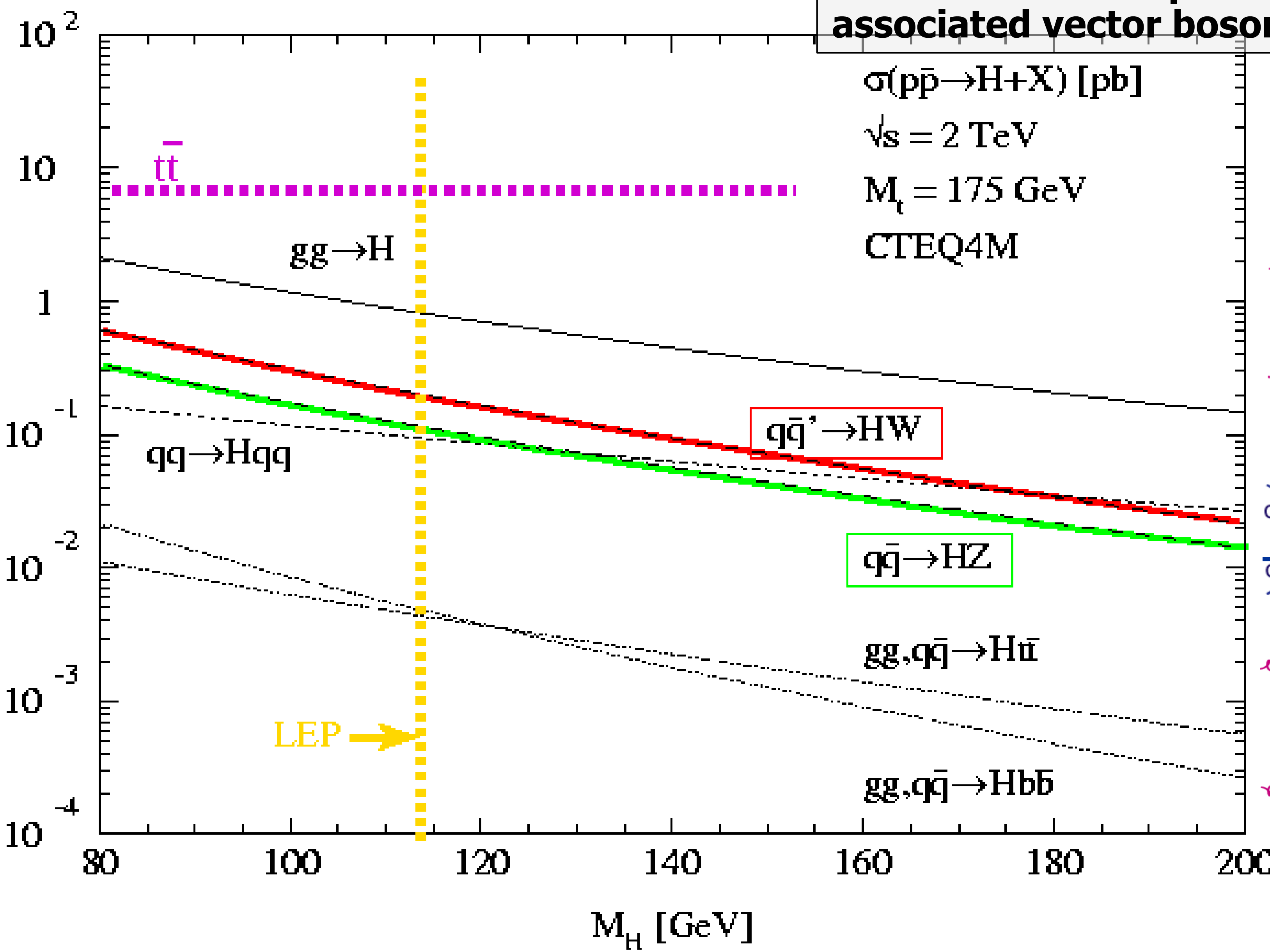
Upgraded
- Calorimeter
- DAQ/trigger
- displaced-vertex trigger

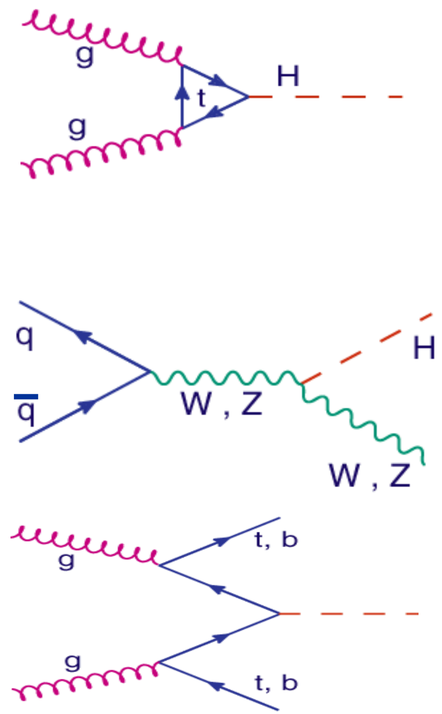
New
- Tracking in B-field
- Silicon detector
- fiber tracker

Upgraded
- Calorimeter, muon system
- DAQ/trigger

Sections efficaces de production au Tevatron

Production cross section (m_H 115-180)
→ in the 0.8-0.2 pb range for gg → H
→ in the 0.2-0.03 pb range for WH associated vector boson production





Canaux de recherche au Tevatron

En collisioneur hadronique il faut chercher des signatures autres que « pure jets »: leptons à grand p_T ou $\not{E}_T$ (ν)

Pour Mh < 130 GeV

production associée avec W ou Z, désintégrations leptoniques de W/Z:

- Wbb : $e\nu$ bb, $\mu\nu$ bb
- Zbb : ee bb, $\mu\mu$ bb, $\nu\nu$ bb
- WWW*: ee+jj+$\nu\nu$, eμ+jj+$\nu\nu$, $\mu\mu$+jj+$\nu\nu$

Pour Mh > 130 GeV:

gg->H->WW* désintégrations leptoniques

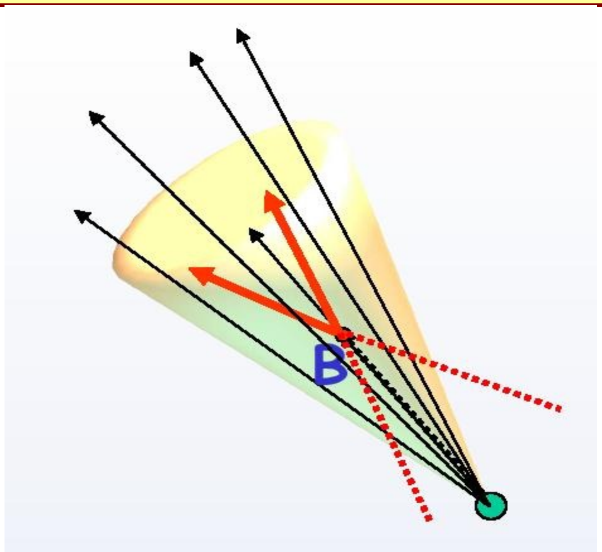
$e\nu e\nu$, $\mu\nu\mu\nu$, $e\nu\mu\nu$

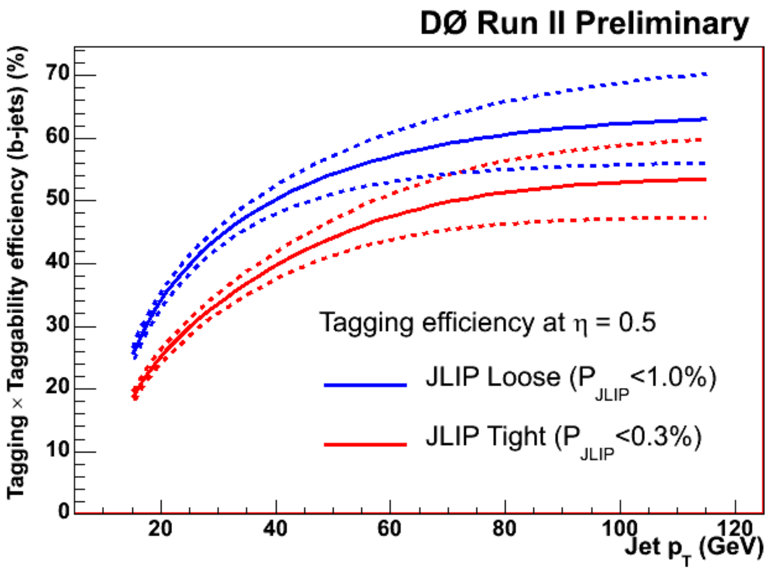
Canal		CDF	D0
WH	$l\nu bb$	1000 pb^{-1}	350 pb^{-1}
	WWW*	190 pb^{-1}	370 pb^{-1}
ZH	llbb	1000 pb^{-1}	900 pb^{-1}
	$\nu\nu bb$	970 pb^{-1}	260 pb^{-1}
H	WW*	360 pb^{-1}	970 pb^{-1}

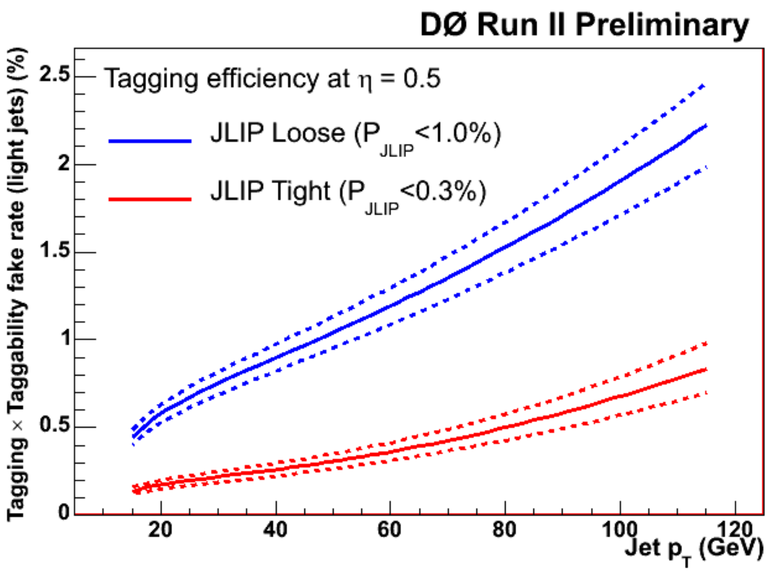
b-tagging

B-hadron are long lived particles $c\tau$~0.5 mm.

Semi-leptonic decay b->$\mu\nu c$



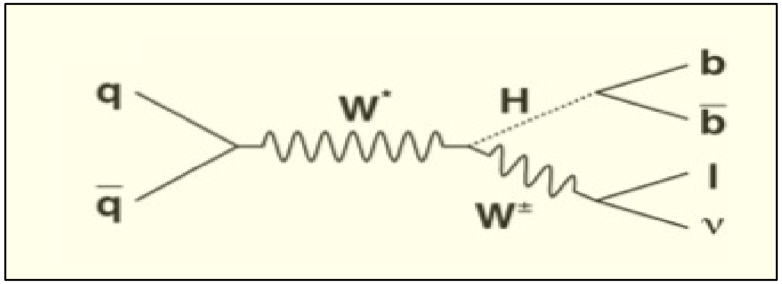


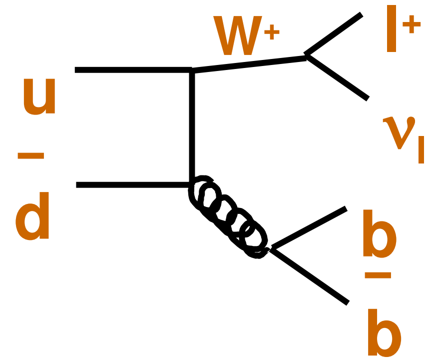


- Can make use of:
  - High impact parameter of tracks
  - Secondary vertex reconstruction
  - Lepton tag
  - b-jet kinematics
  - combination of above with multivariate technics (eg ANN)
- Eg CDF 2nd vertex tag:
  - ε=50% for 0.6% mis-tag at η<1
- Eg: D0 IP tag:
  - ε=50% for 1% mis-tag at η=0.5

Basses masses

WH -> lν bb



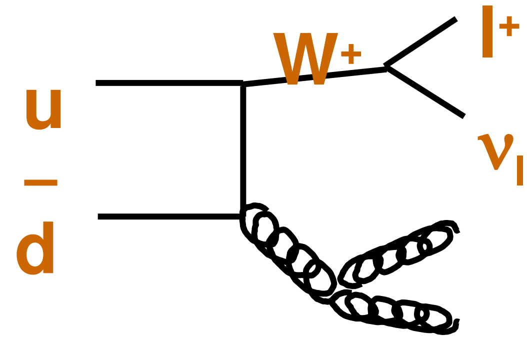


Most difficult
Large background
(also Wcc)

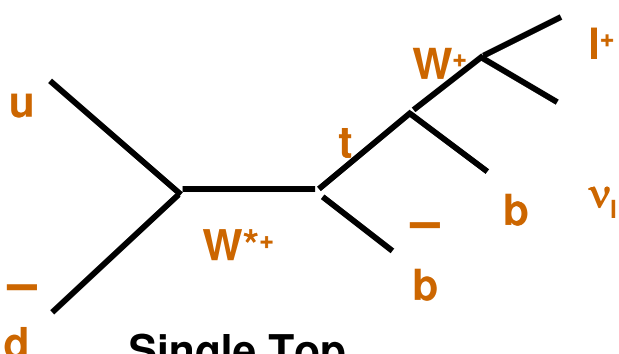
2 b jets ~ 50 GeV

1 lepton ~ 40 GeV

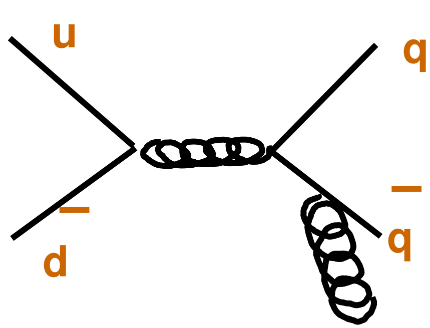
Missing E_T ~ 40 GeV



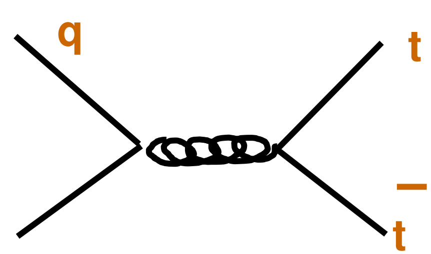
W+2 light jet
with one/two
false b-tag



Single Top



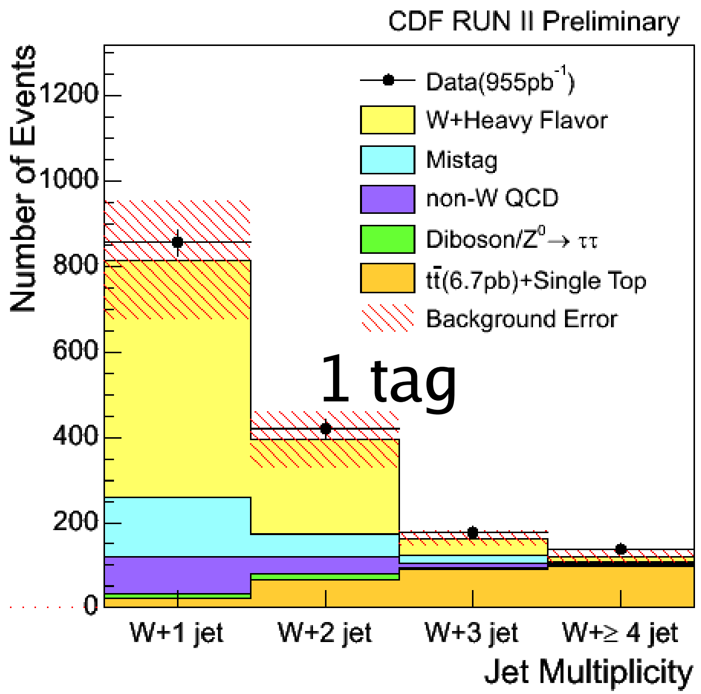
“Non-W from QCD”

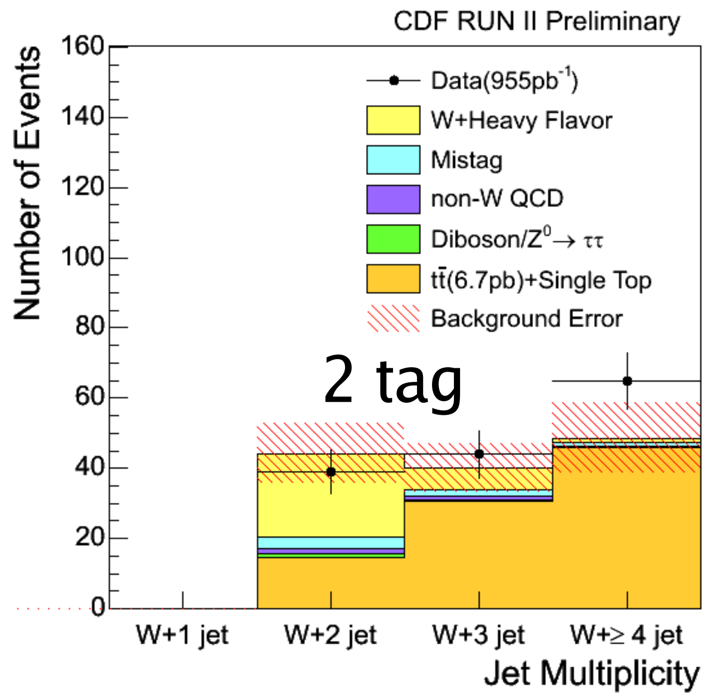


“ttbar”:
Jets+leptons
from W decay

CDF: WH->Wbb 960 pb^{-1}

- Sélection
  - lepton isolé, central e/μ. p_T>20 GeV
  - $\not{E}_T$ > 20 GeV
  - Exactement 2 jets: E_T>15, $|\eta|$<2
  - Combinaison exclusive de 2 sélections
    - Exactement 1 jet b-tag (NN)
    - 2 jets avec Secondary Vertex tag
- Bdf
  - W+jets mesuré dans les données
  - W+bb/W+jets MC Alpgen

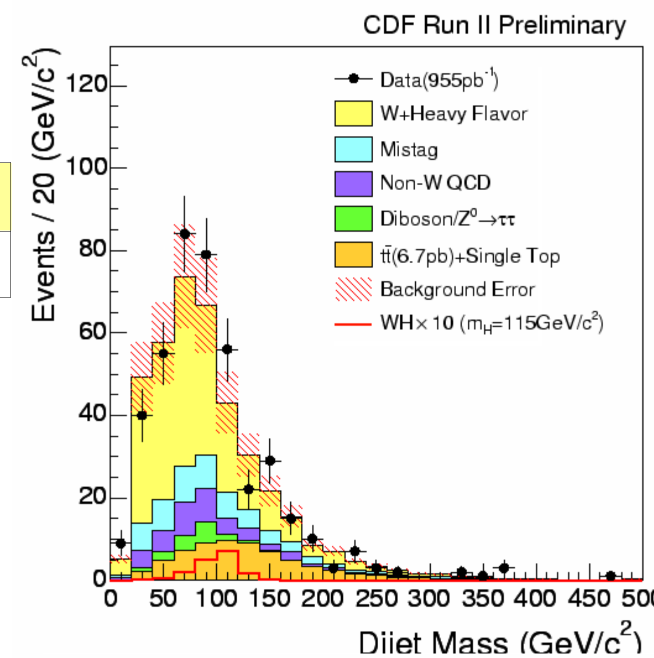




CDF: WH->Wbb 960 pb^{-1}

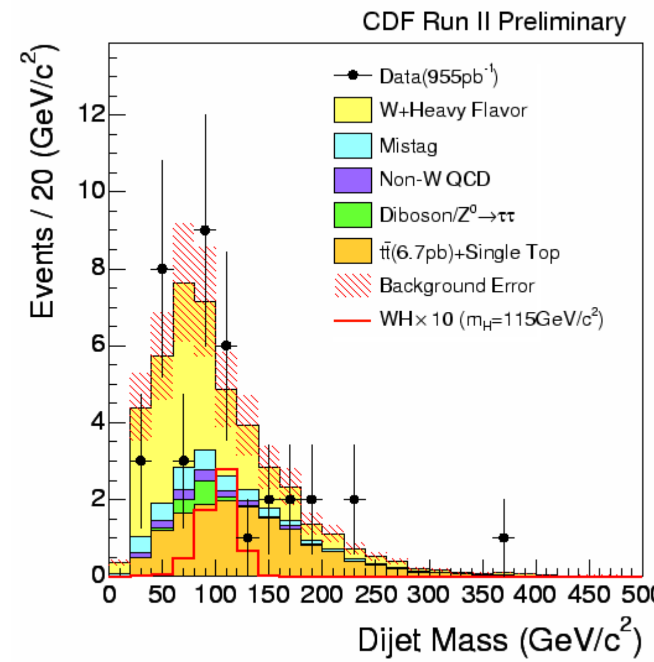
exemple sélection 2 tag

Mistag	Wc(c)	Wbb	tt+t	Other	total	Data
3.5±0.5	3.3±1.1	20.3±7	14.±3	2.6±0.5	44.2±8.5	39



systématiques

Source	Uncertainty (%)	
	= 1tag w/ NNtag	≥ 2tag
Lepton ID	∼2%	
Trigger	< 1%	
ISR	1.8%	4.3%
FSR	3.2%	8.6%
PDF	1.7%	2.0%
JES	2.3%	3.0%
b-tagging	5.3%	16%
Total	7.2%	19.1%



Pour m_H=115

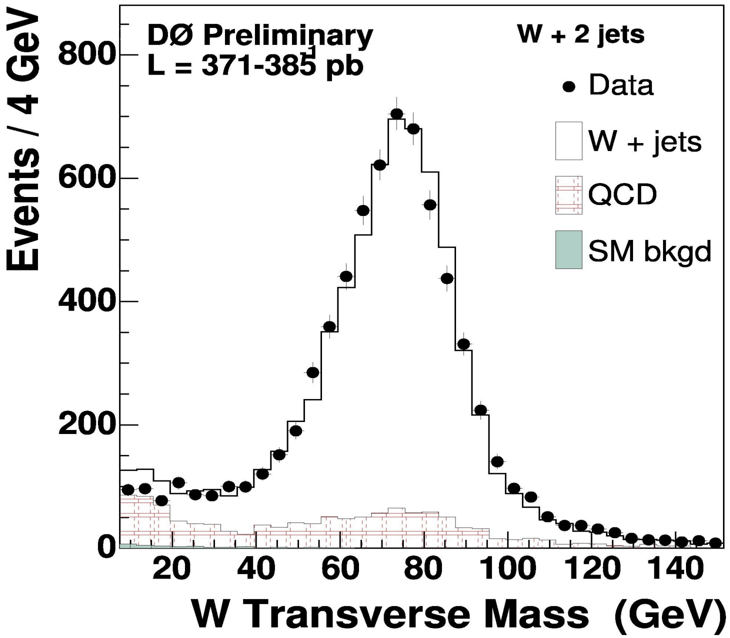
$\sigma(WH)\times B(H\to bb)$ <3.4 pb @95% GeV

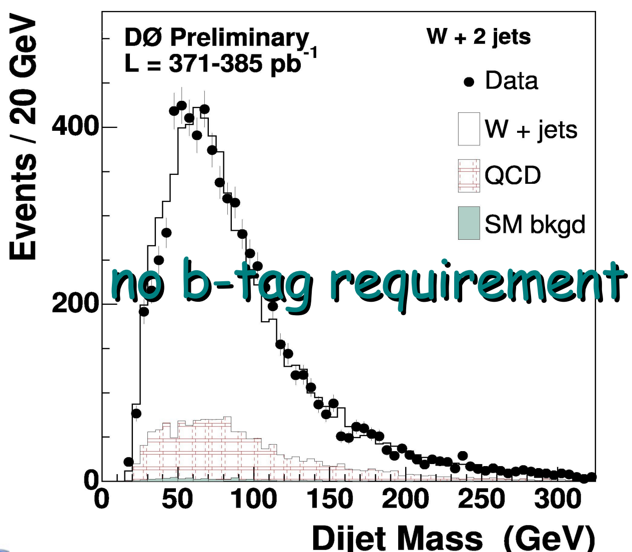
$\sigma_{95}/\sigma(SM)$ ~ 26

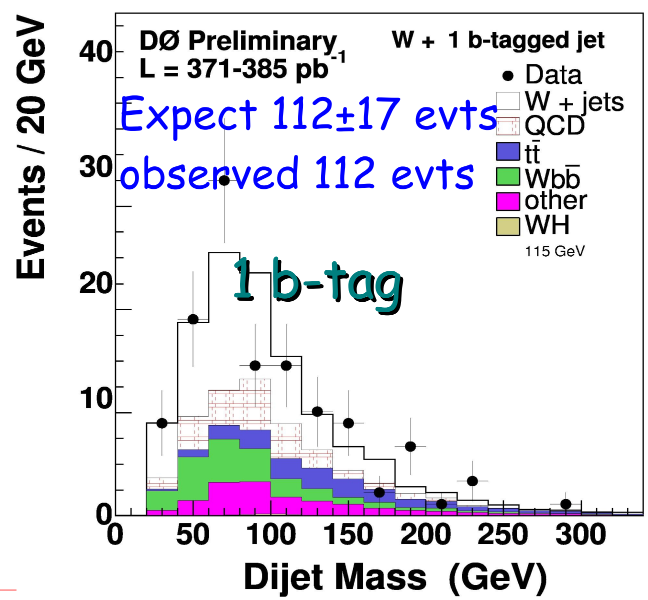
DØ: WH->Wbb

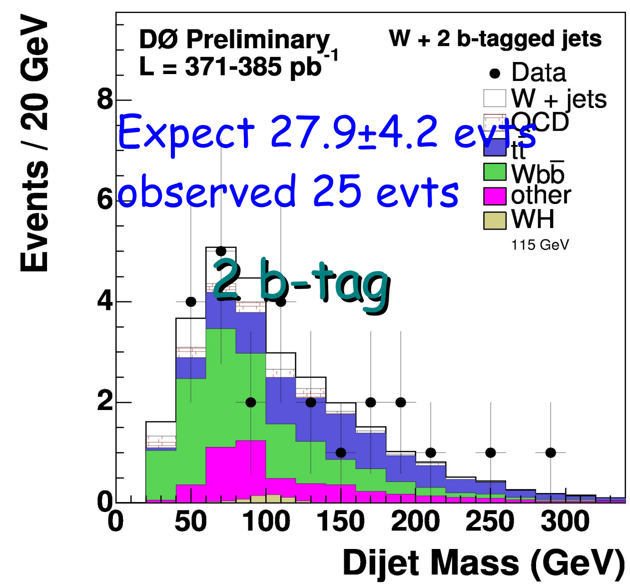
- Sélection
  - lepton isolé p_T>20 GeV
  - $\not{E}_T$ > 25 GeV
  - ≥2 jets: E_T>20, Gev $|\eta|$<2.5
  - 2 samples exclusifs
    - 1 b-tag tight
    - 2 b-tag loose
- Bdf
  - W+jets mesuré dans les données
  - W+bb MC Alpgen, K factor MCF@NLO

7388 evts for L~380 pb^{-1}





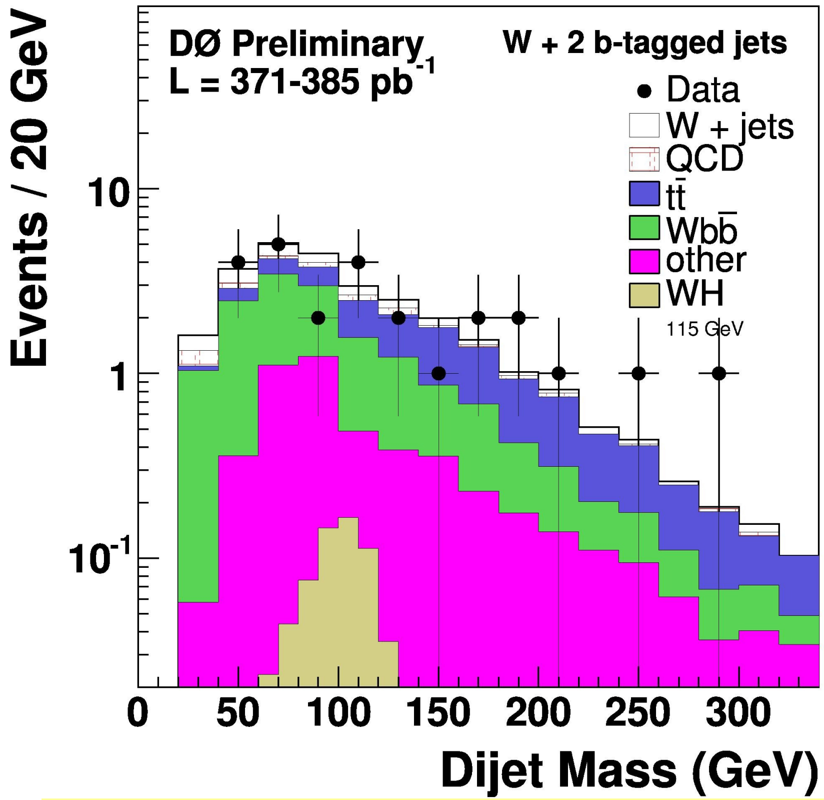




DØ: WH->Wbb 380 pb^{-1}

- Eg sélection 2tag

Mistag	diboson	Wbb	tt+t	QCD	total	Observed
3.5±0.6	1.6±0.3	10.8± 2.4	9.3±1.9	1.4±0.6	27.9±4.2	25



- Systematics on Higgs production
  - Jet energy scale 5%
  - Jet ID 7%
  - Trigger-leptonID 6%
  - MC simulations 5%
  - B-tagging 9%

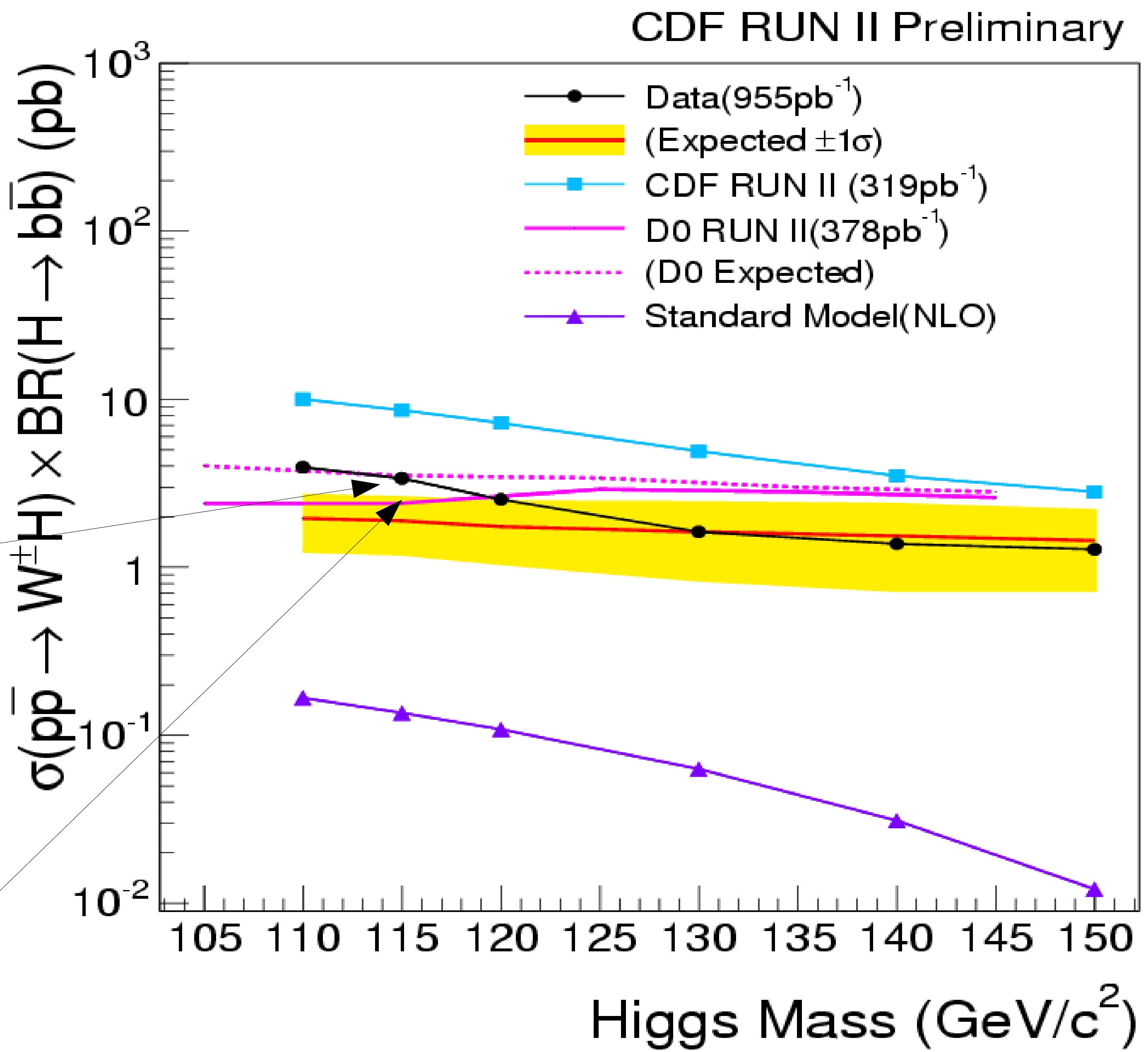
  TOTAL 15%

Pour m_H=115

$\sigma(WH)\times B(H\to bb) < 2.4$ pb @95% GeV

$\sigma_{95}/\sigma(SM) \sim 17$

Résultats CDF et DØ pour Wbb

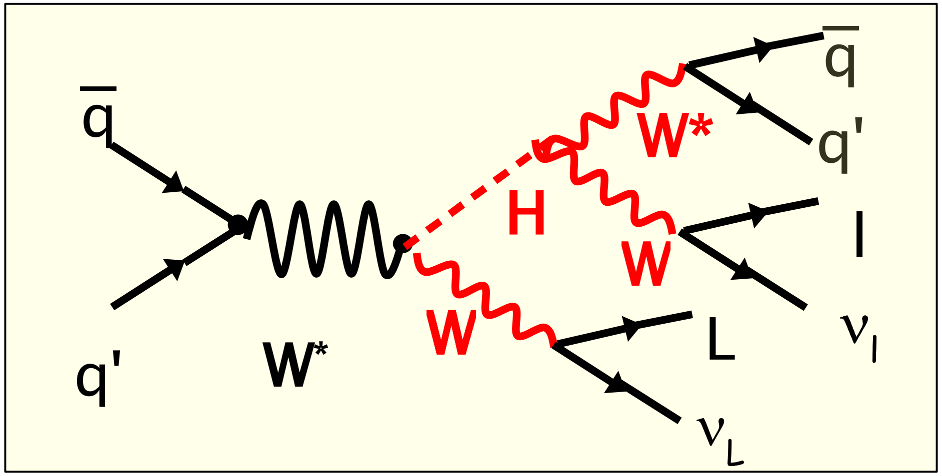


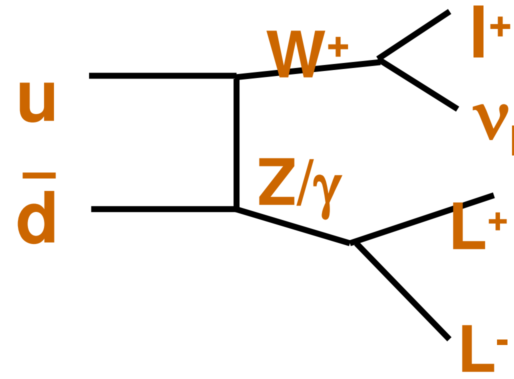
Pour m_H=115 @95% CL

CDF 955 pb^{-1}
$\sigma(WH) \times B(H\text{->}bb) < 3.4$ pb
$\sigma_{95}/\sigma(SM)$ ~ 26
(Limite "malchanceuse")

D0 320 pb^{-1}
$\sigma(WH) \times B(H\text{->}bb) < 2.4$ pb
$\sigma_{95}/\sigma(SM)$ ~ 17
(Limite "chanceuse")

HW -> WWW* -> llνν jj



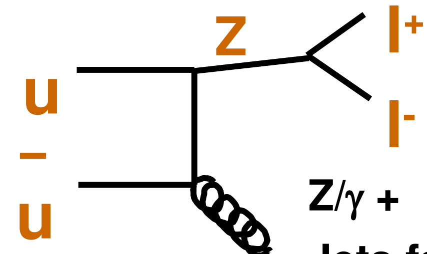


WZ

+1 lepton non détecté

2 leptons même charge ~ 40 GeV

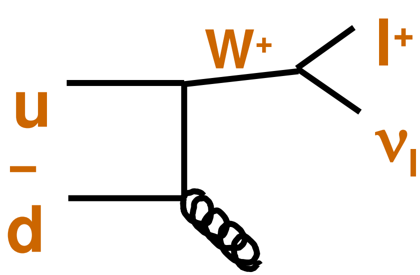
Missing E_T ~ 40 GeV



Z/γ +

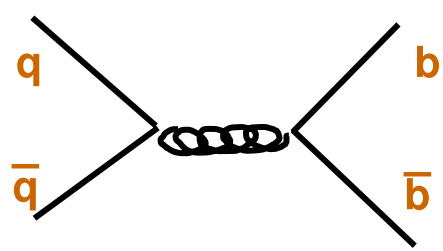
Jets faking MET

charge mal estimée



W+jet

Jet faking lepton

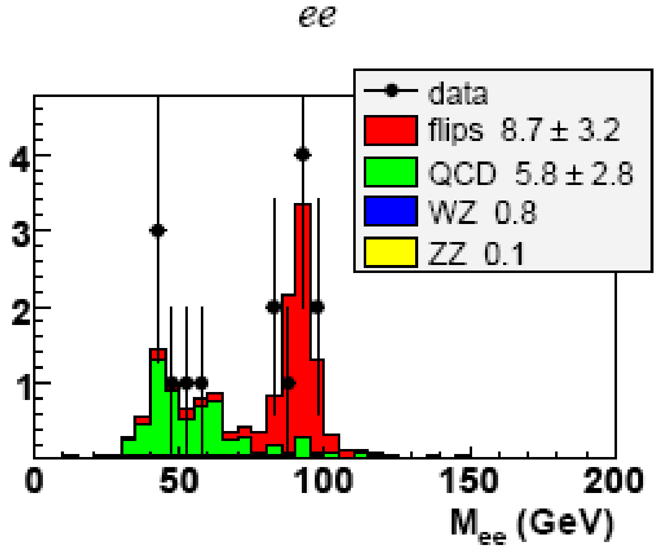


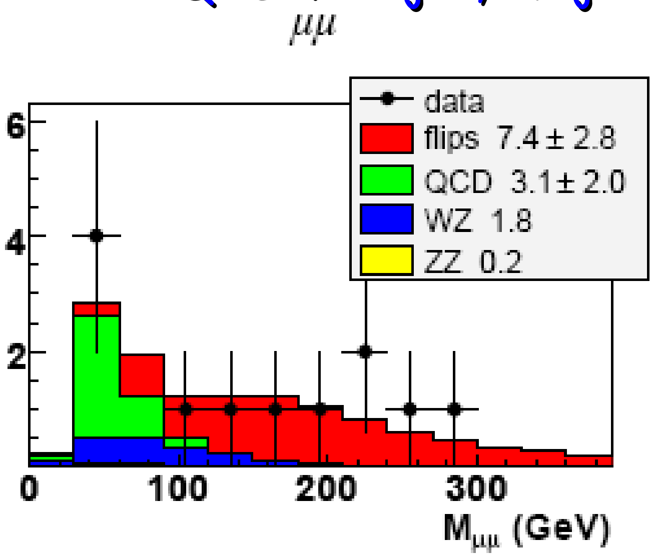
2 Jets

produisant 2 leptons

DØ: H->WWW* -> llνν (370 pb⁻¹)

- **Présélection**
  - 2 leptons isolés p_T >15 GeV
  - même charge
  - $\not{E}_T$ > 20 GeV
- **Bruit de fond:**
  - WZ production obtenu du MC
  - inversion de charge provenant des données (probabilité ~ 10^{-3})
  - QCD multijet, W+jets <= données

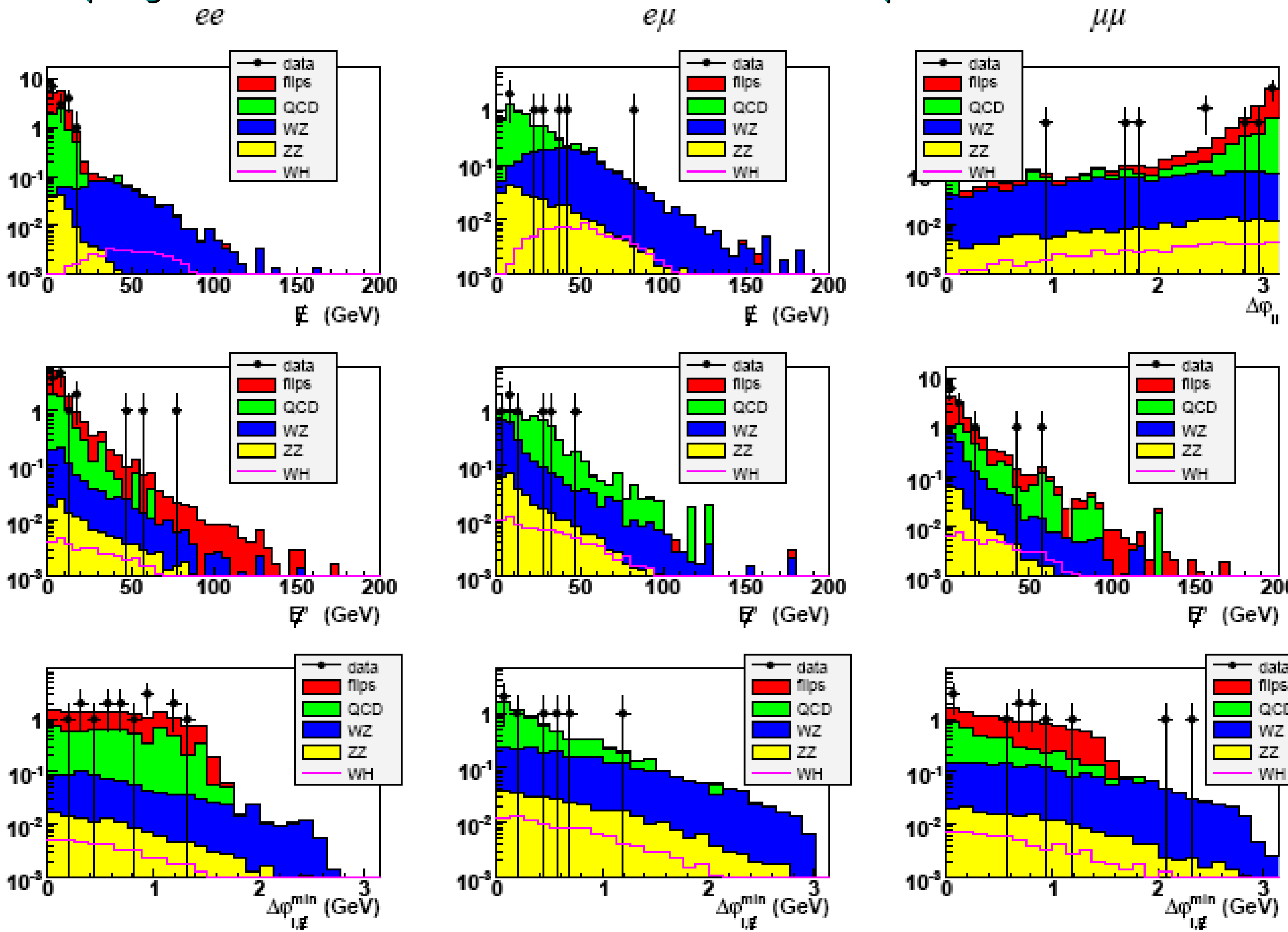




	ee	$e\mu$	$\mu\mu$
data	15	7	12
charge flips	8.73± 3.33	0.17± 0.05	7.38± 2.91
W/QCD	5.80± 2.92	4.38± 0.26	3.11± 2.10
WZ	0.77± 0.08	2.11± 0.25	1.77± 0.25
ZZ	0.13± 0.01	0.31± 0.03	0.21± 0.03
total	15.43± 3.93	6.97± 0.37	12.47± 3.50

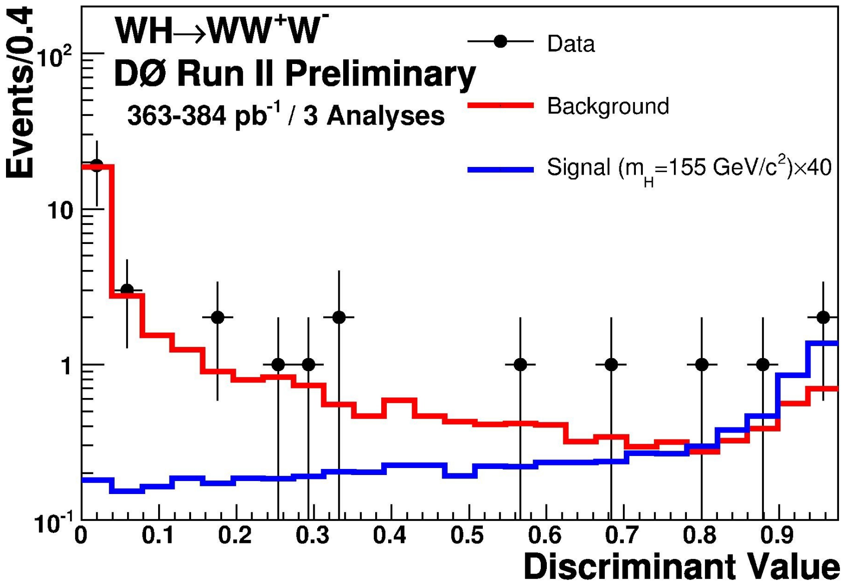
DØ: sélection WWW*

Topological Likelihood discriminant, built on 3 variables per channel



résultats WWW*

- Résultat D0 après coupure sur likelihood:

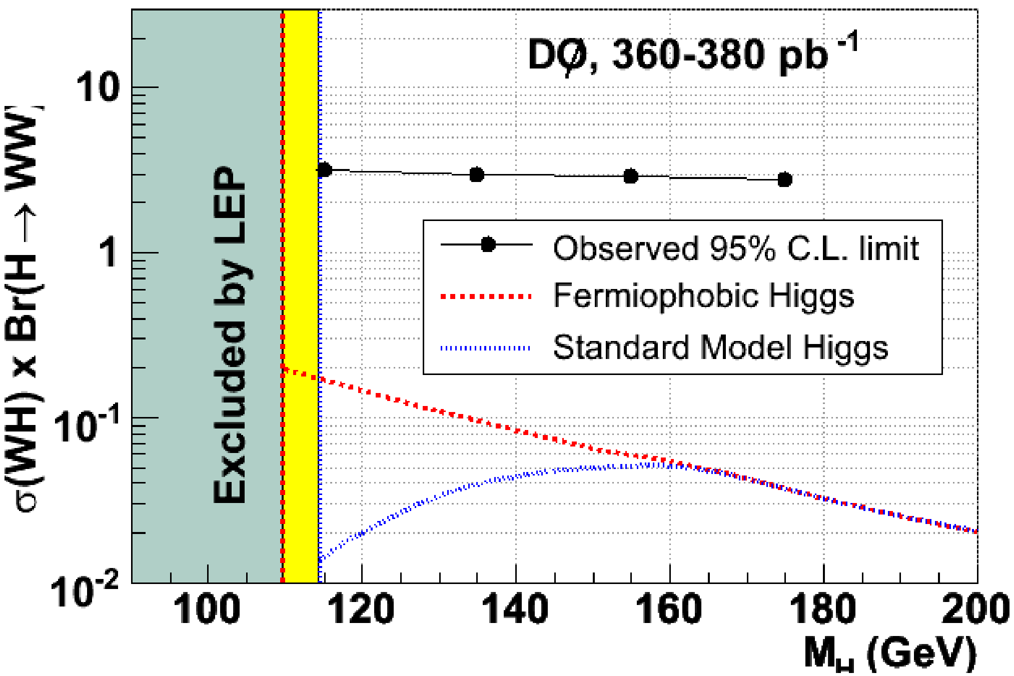


$M_H = 155$ GeV

	ee	$e\mu$	$\mu\mu$
data	1	3	2
charge flips	0.16± 0.06	0.03± 0.01	0.96± 0.38
W/QCD	0.09± 0.04	0.70± 0.01	0.79± 0.54
WZ	0.31± 0.03	0.74± 0.09	0.46± 0.07
ZZ	0.02± 0.01	0.09± 0.01	0.06± 0.01
total	0.58± 0.09	1.55± 0.13	2.28± 0.65

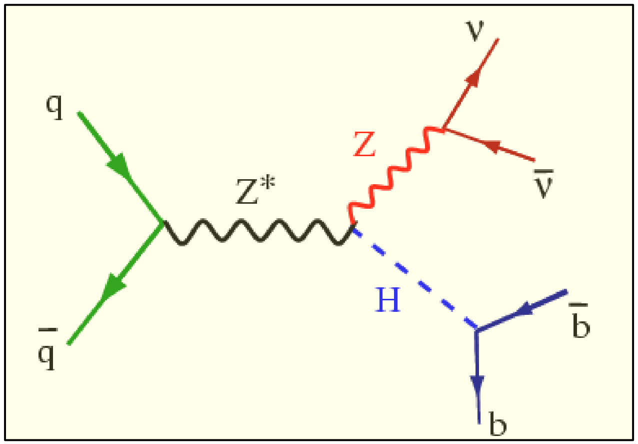
pour m_H=160 GeV
CDF 194 pb^{-1}:
σxB(H->WW) <8 pb @95%

DØ 360 pb^{-1}:
σxB(H->WW) <2.9 pb @95%
$\sigma_{95}/\sigma(SM)$ ~60



ZH -> νν bb

ZH ⇒ ν ν bb

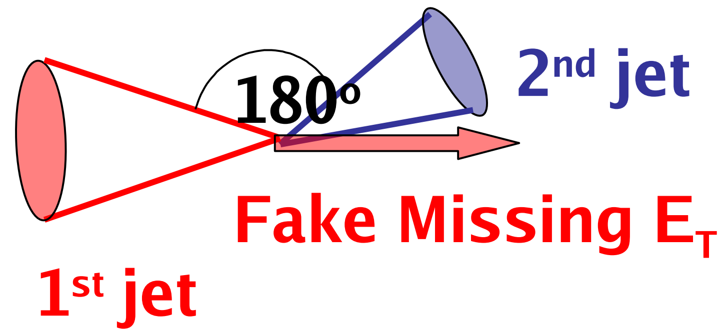


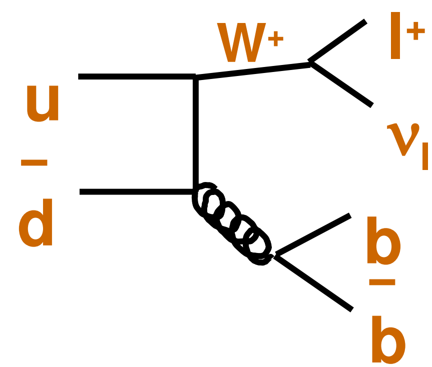
2 b jets ~ 50 GeV

Missing E_T ~ 90 GeV

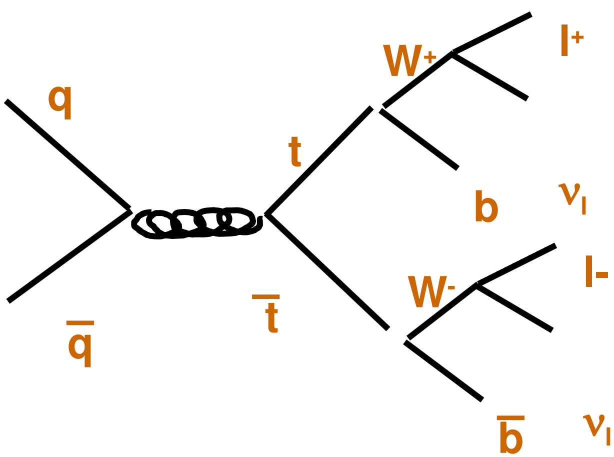
Most difficult background:

QCD Di-jet ($\bar{b}b$)

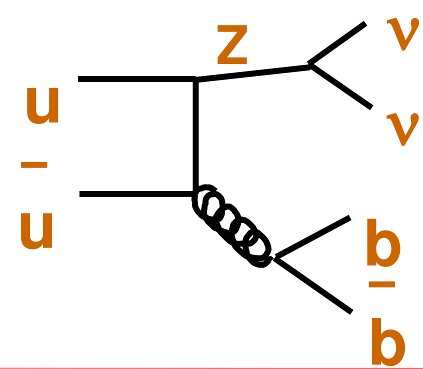




Wbb avec lepton non détecté

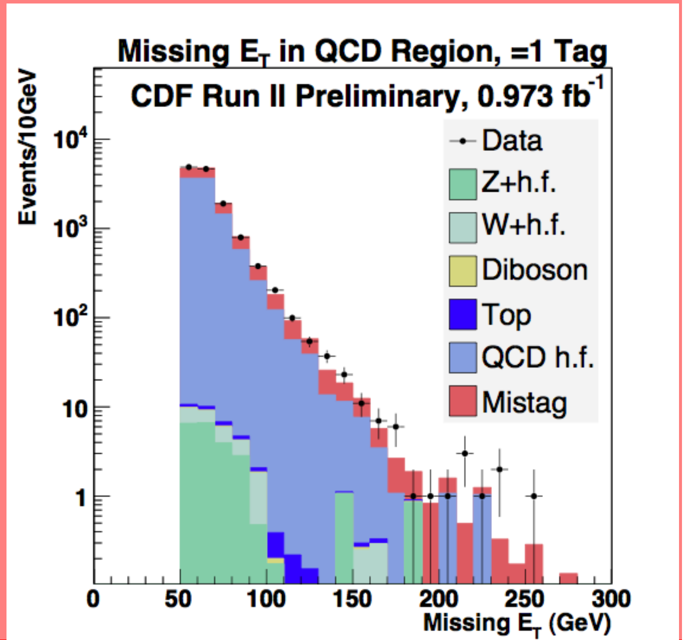


Production de top avec 2 leptons non détectés



Zbb

CDF : ZH->ννbb - 1 fb^{-1}

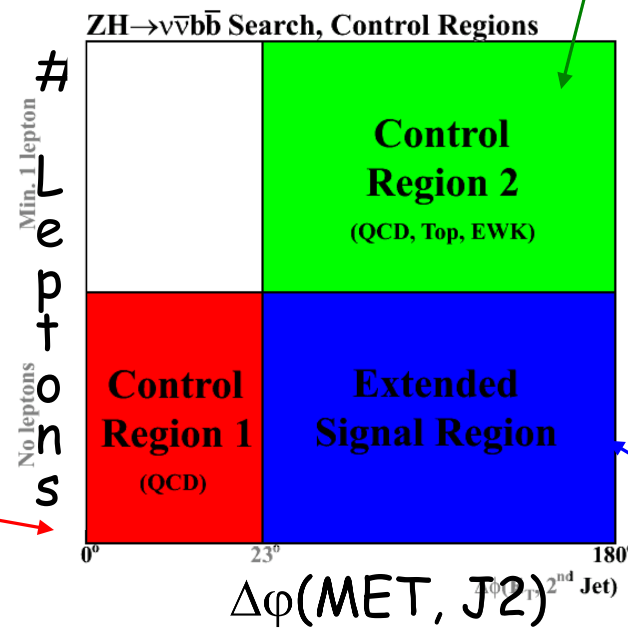


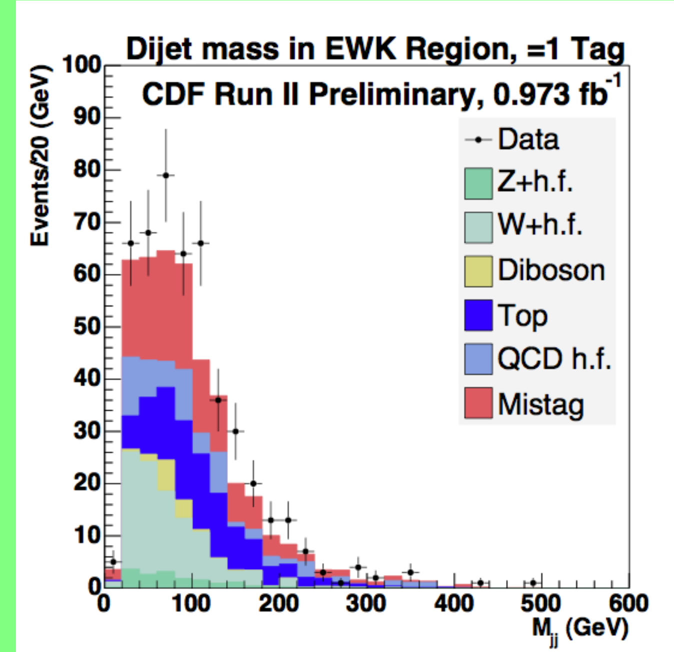
MET in QCD control region:

- no leptons
- met close to second jet

M_{jj} in EWK control region:

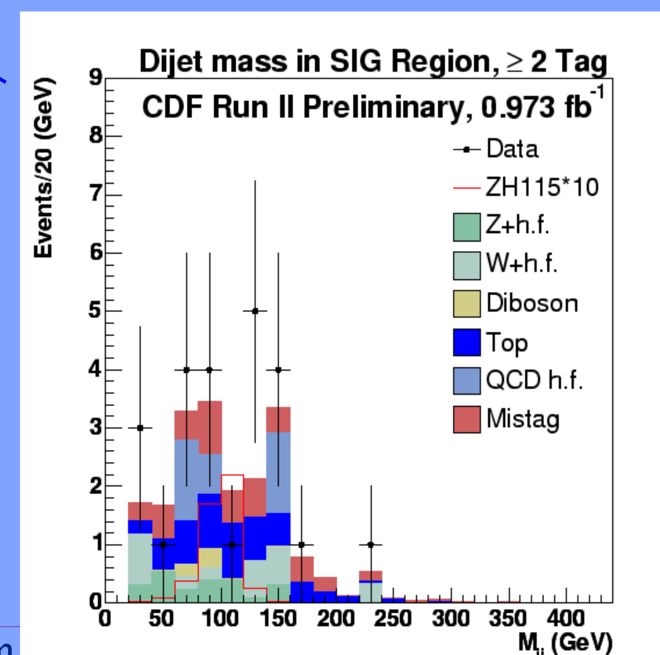
- one lepton
- met away from second jet





M_{jj} Signal region:

- no leptons
- met away from second jet



CDF : ZH->ννbb - 1fb^{-1}

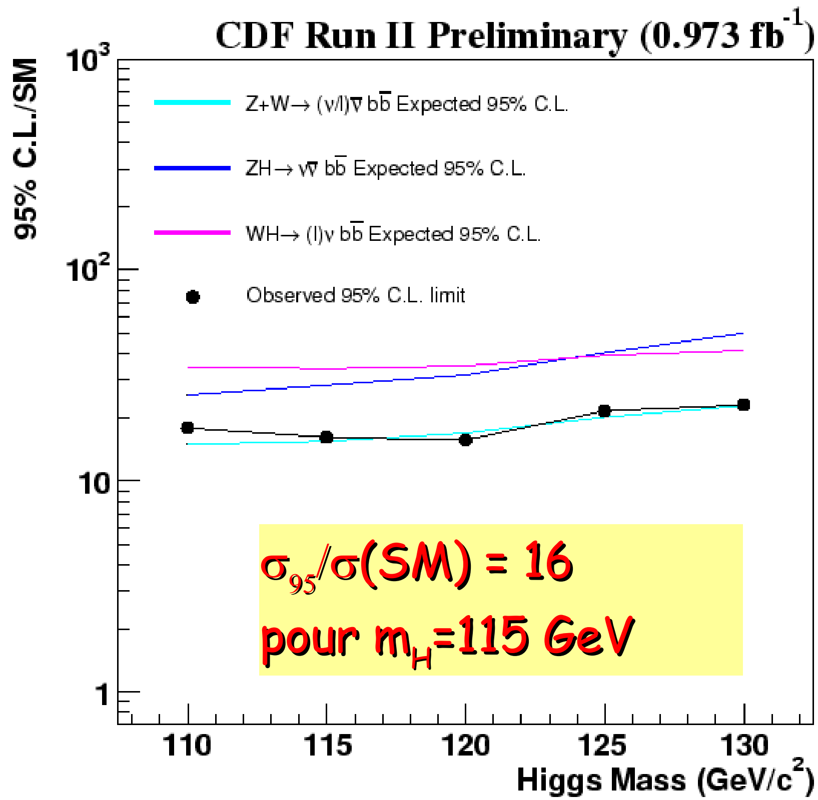
- Exactement 2 jets: E_T>60,20 Gev |η|<2.4
- $\not{E}_T$ > 75 GeV
- Δφ(MET, J2)>0.8
- 2 sélections exclusive
  - 1 b-tag, 2 b-tag
- sélection sensible aussi au signal

WH -> lνbb (lepton non détecté)

qques chiffres

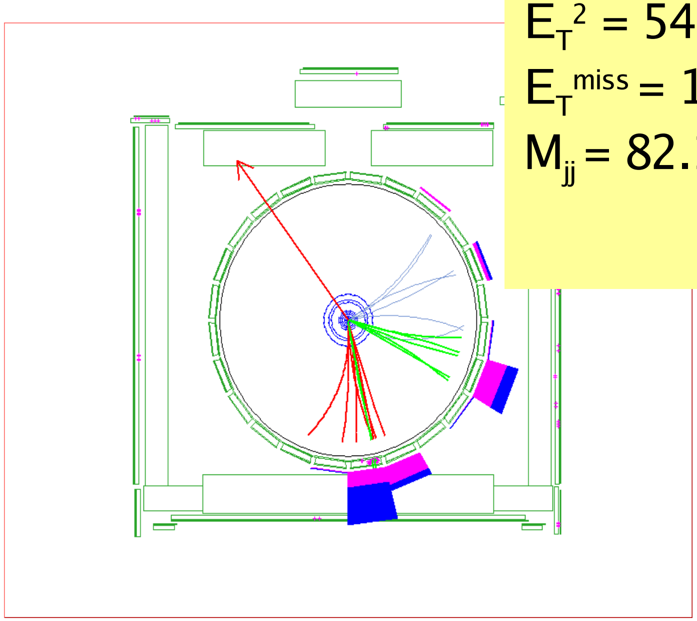
2 b-tag

QCD hf	3.5±1.7
Mistag	4.8±0.9
top	5.5± 1.1
W+hf	2.9±1.4
Z+hf	2.3±0.6
diboson	0.6±0.1
total	19.6±3.1
observed	24



$\sigma_{95}/\sigma(SM) = 16$

pour m_H=115 GeV



E_T^1 = 100.3 GeV

E_T^2 = 54.7 GeV

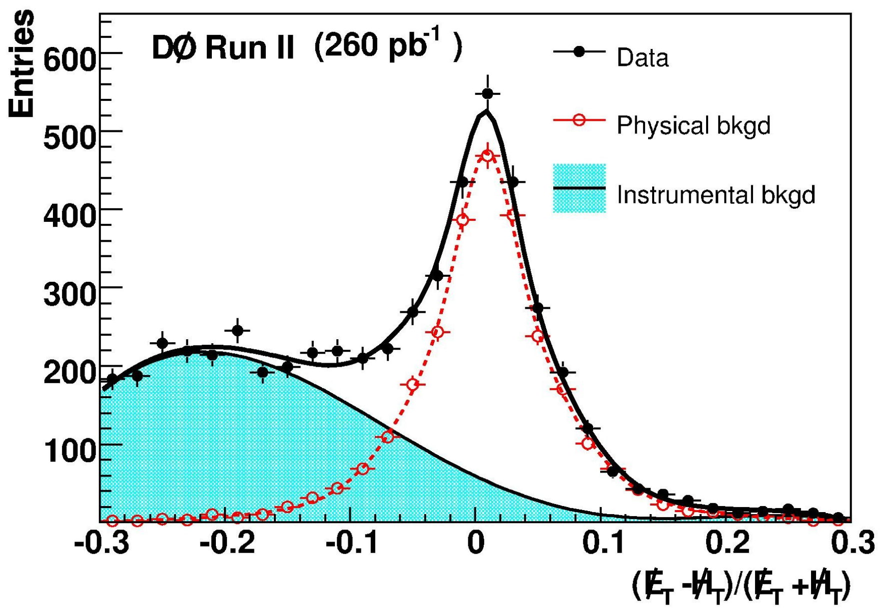
E_T^{miss} = 144.8 GeV

M_{jj} = 82.1 GeV

DØ : ZH->νν bb - 260 pb^{-1}

- 2 jets acoplanaires
  - E_T > 20 GeV
  - $\not{E}_T$ > 50 GeV
  - $\Delta\phi$(dijet) < 165°
  - Sum of scalar jet E_T < 240 GeV

- 2 samples exclusifs:
  - 1 b-tag tight
  - 2 b-tag loose



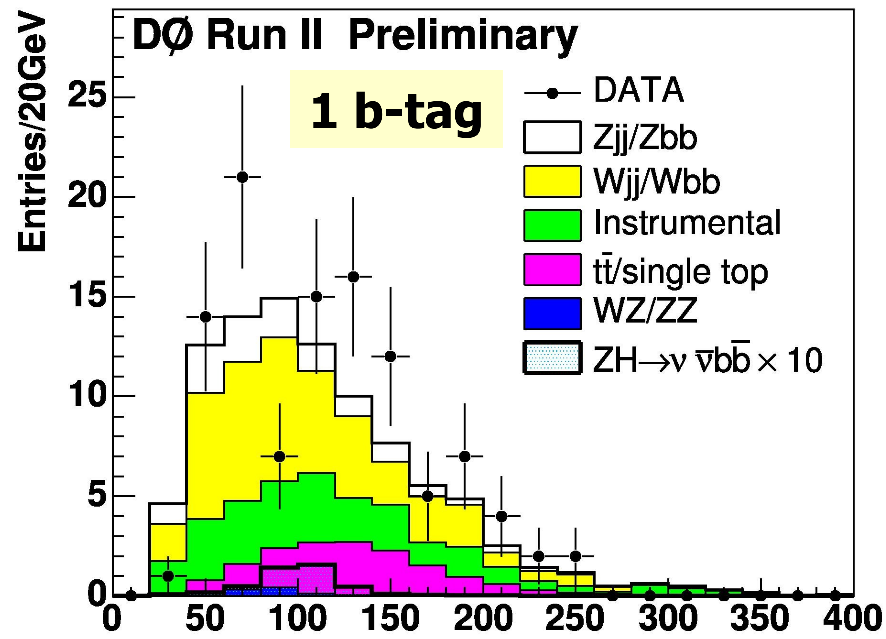
- Bdf instrumental (mismeasured $\not{E}_T$) estimé en étudiant l'asymétrie
  - $\not{E}_T$ calculated using calorimeter cells
  - $\not{H}_T$ = - $|\Sigma p_T(\text{jet})|$ ... jets

DØ : ZH->ννbb - 260 pb^{-1}

Pour mH = 115 GeV

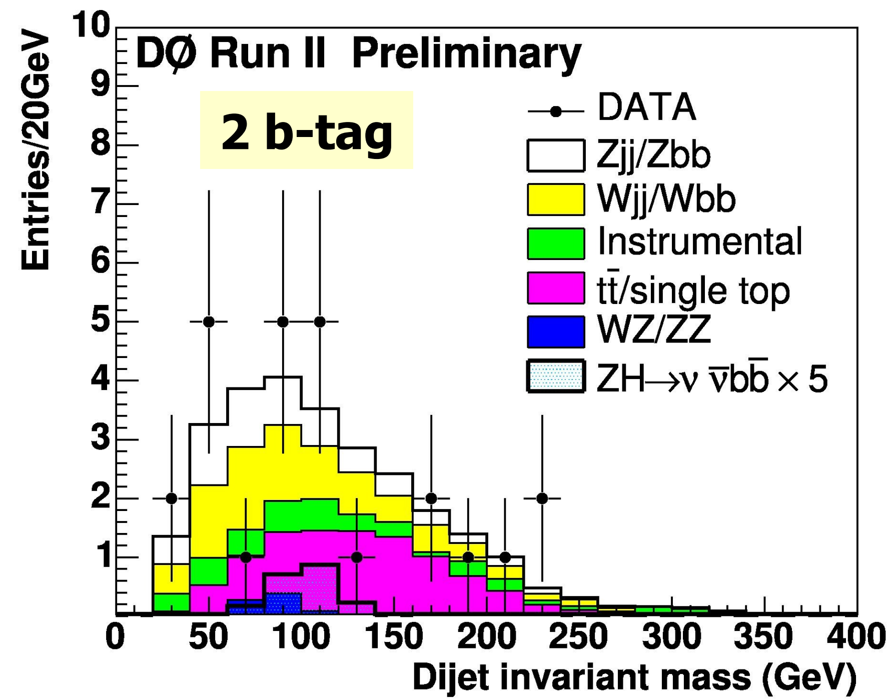
75 < mjj < 125 GeV:

- 11 events observed
- 9.4 +/- 1.8 predicted

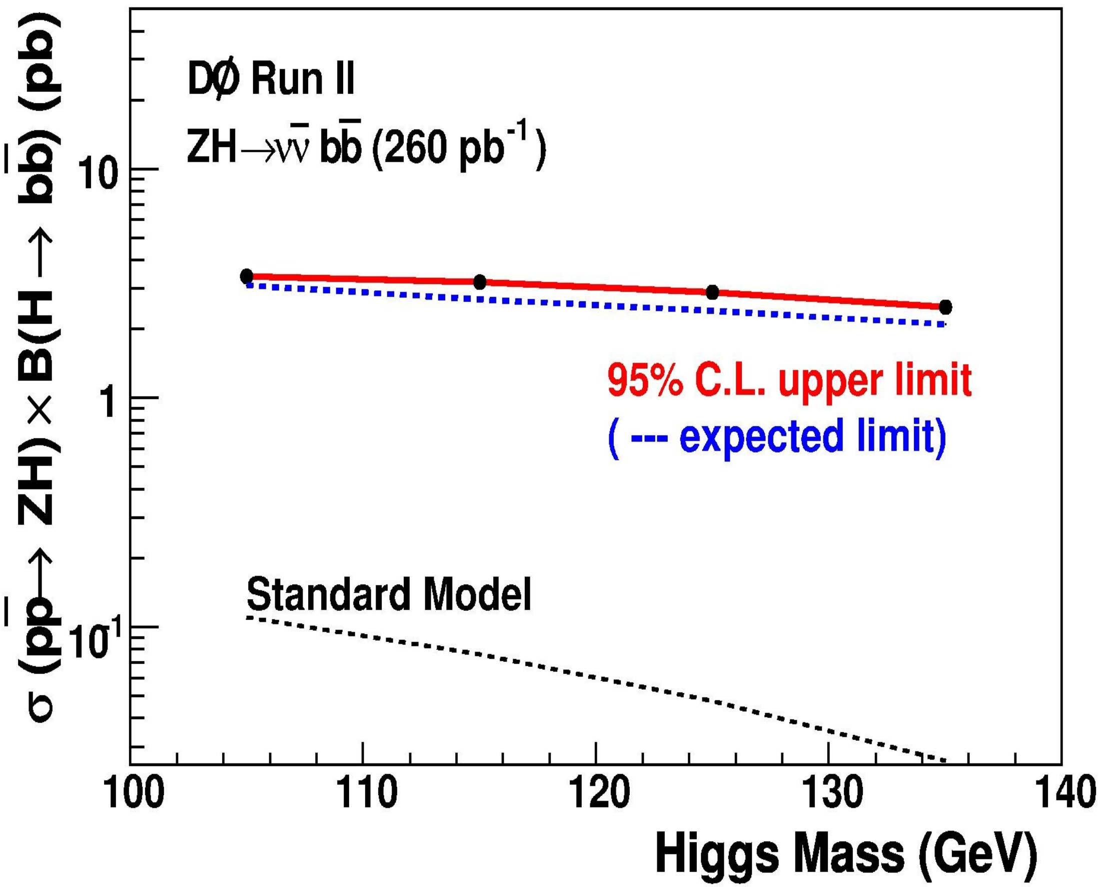


Systematic uncertainty, DT (%)

Source	Sig	bkgd
Trigger efficiency	6	6
Jet ID	7	6
JES	7	8
Jet energy resolution	5	2
b-tagging	14	12
Instrumental bkgd.	-	9
Bkgd Cross Section	-	5
Total for DT	19	19
Total for ST	14	18

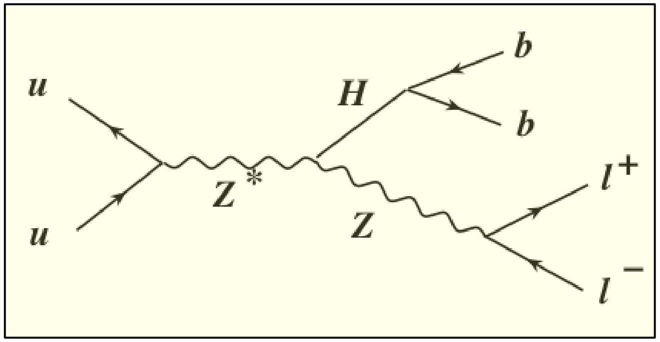


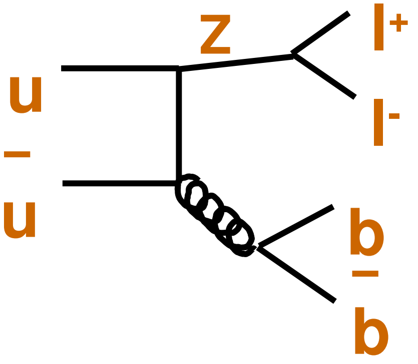
DØ : ZH->ννbb - 260 pb^{-1}



DØ 260 pb^{-1}:
σxB(H->bb) <3.2 pb @95%
$\sigma_{95}/\sigma(SM)$ ~ 40

ZH -> llbb





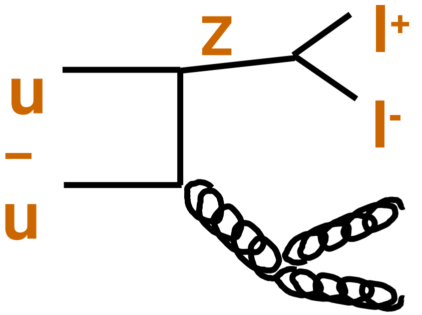
Z+bb

2 b jets ~ 50 GeV each

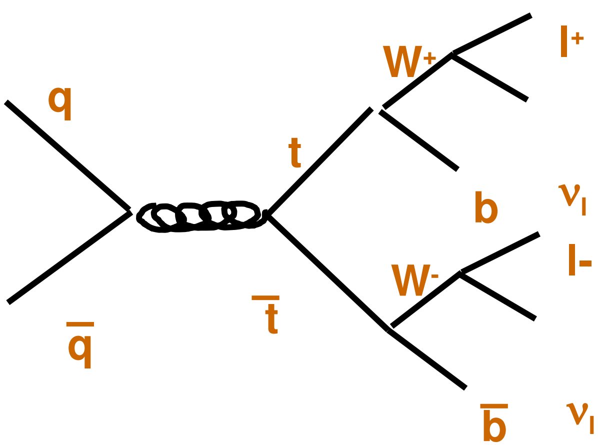
2 leptons ~ 40 GeV each

Z mass constraint

Cleanest signal

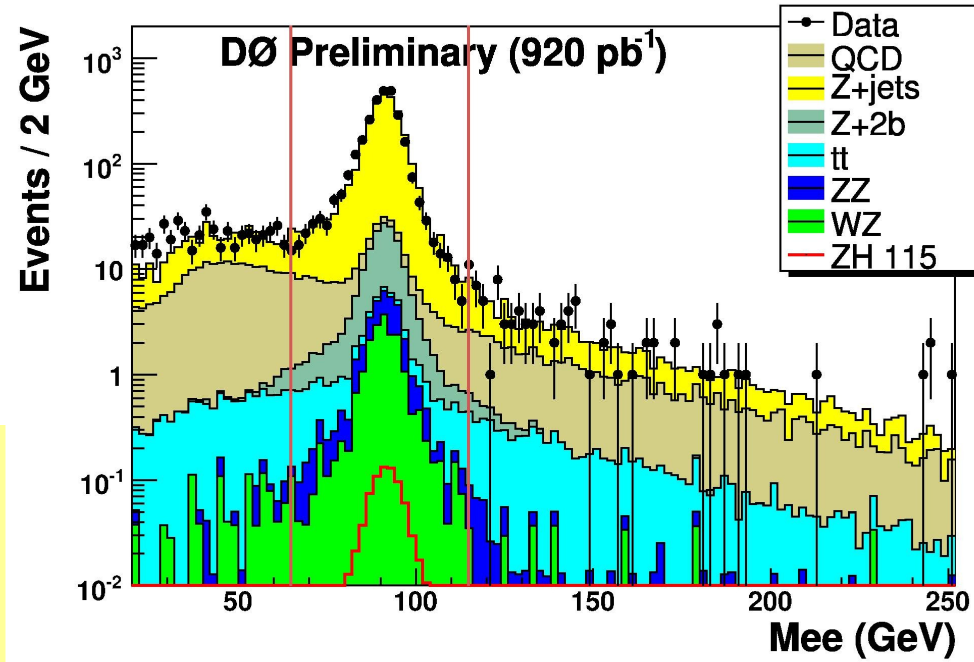


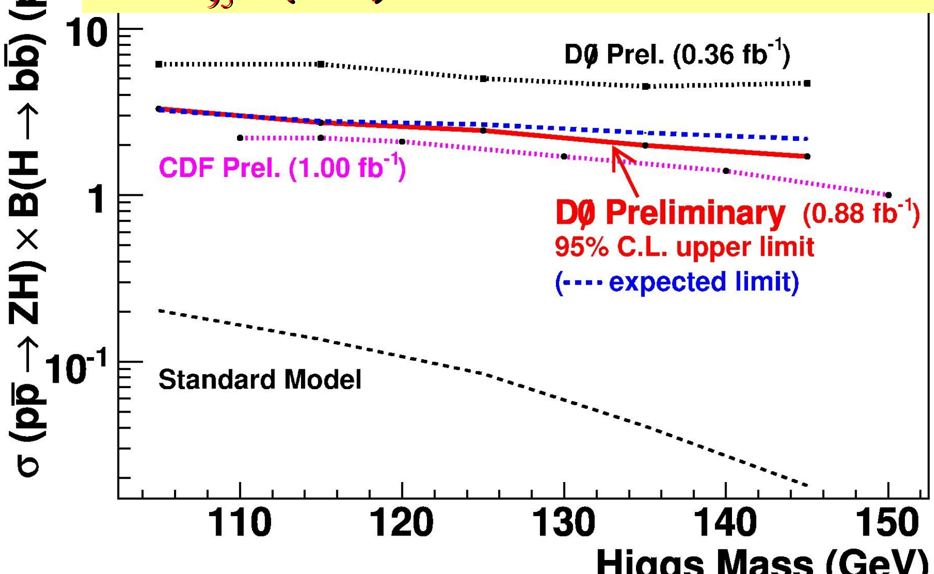
Z+ jets
(mistag)

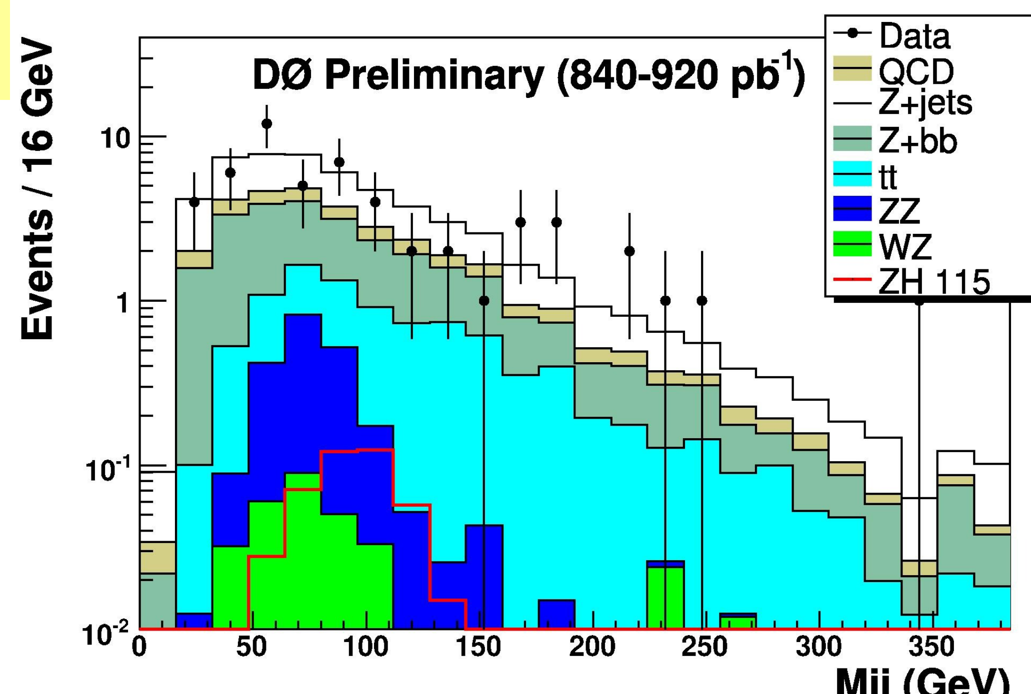


DØ : ZH -> llbb (30 oct 2006)

- 2 isolated leptons. p_T>15 GeV
  - $\not{E}_T$ > 25 GeV
  - ≥2 jets: E_T>15, Gev $|\eta|$<2.5
  - 65<M_{ee}<115 GeV 70<$M_{\mu\mu}$<110 GeV
- 2 b-tag loose
- Pour m_H=115 GeV
  - Bdf attendu = 21.7±7.5
  - Candidats 23
  - σ(ZH)xB(H->bb) <2.7 pb @95%
  - $\sigma_{95}/\sigma(SM)$ = 33

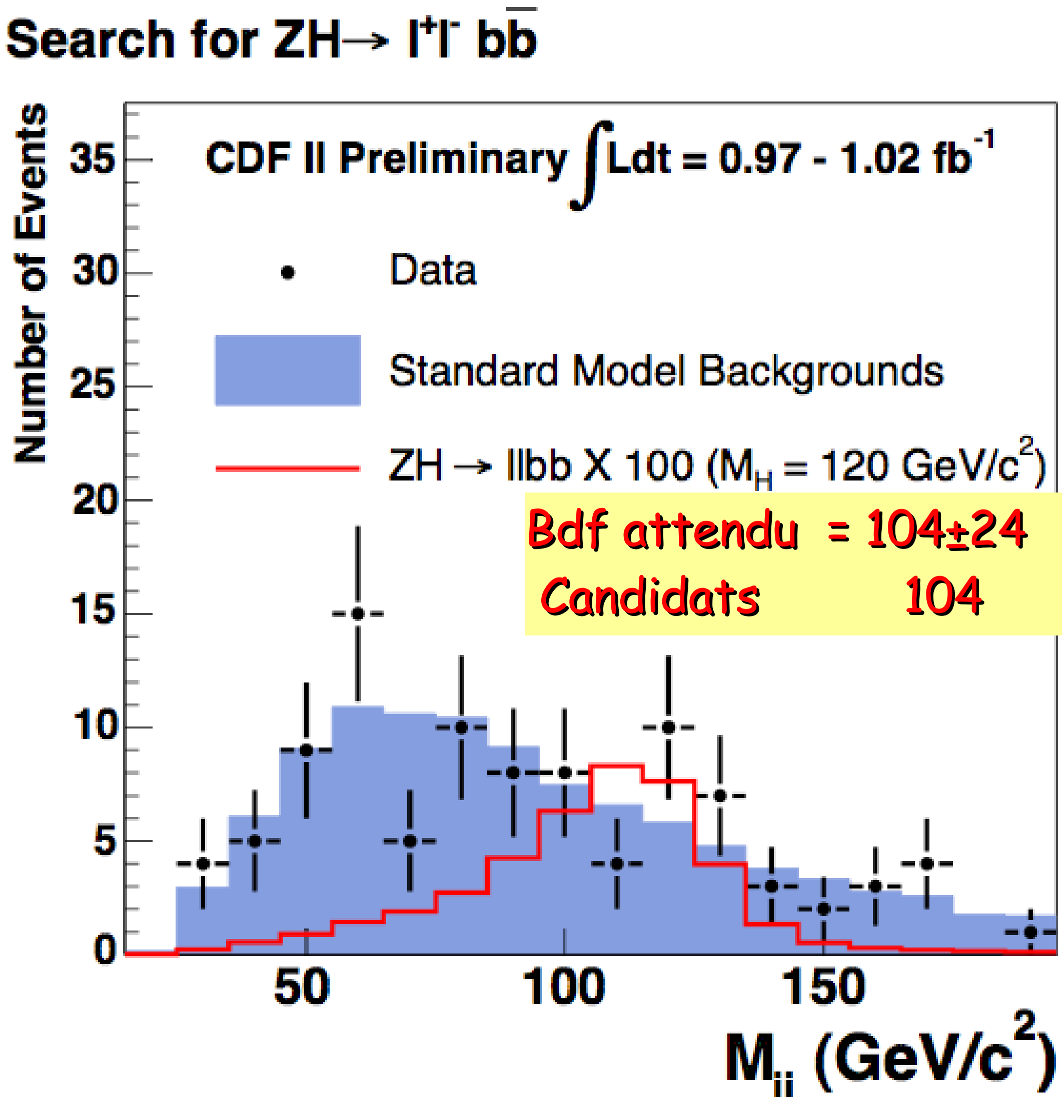






CDF : ZH -> llbb - 1fb^{-1}

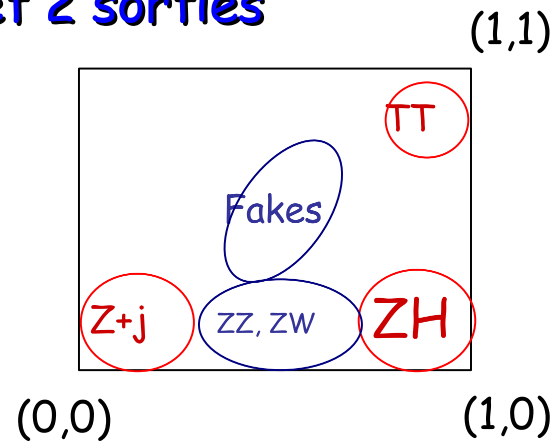
- Sélection
  - 2 leptons à grand p_T
  - $76 < M_{ll} < 106$ GeV
  - 2 jets $p_T > 15, 25$ GeV
  - 1 b-tag

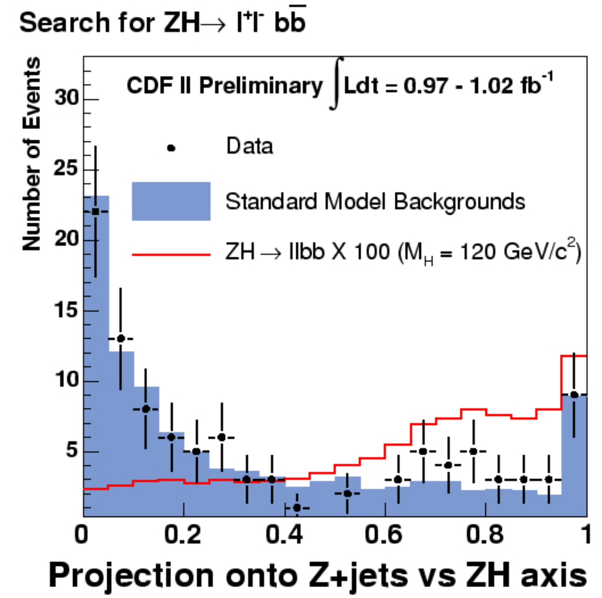


Bdf attendu = 104±24
Candidats 104

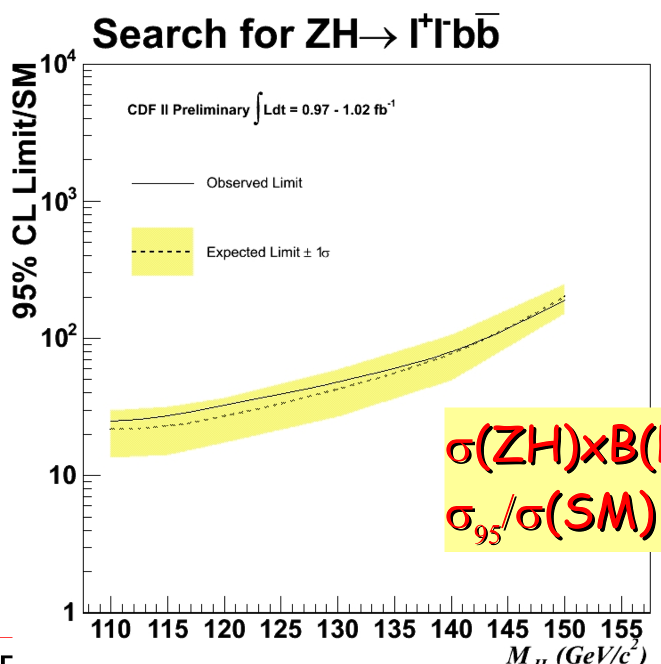
CDF : ZH -> llbb - 1fb^{-1}

- Pour une meilleur discrimination signal/bdf: réseau de neurones à neuf variables d'entrées et 2 sorties
  - Anti top
  - Anti Z+jets



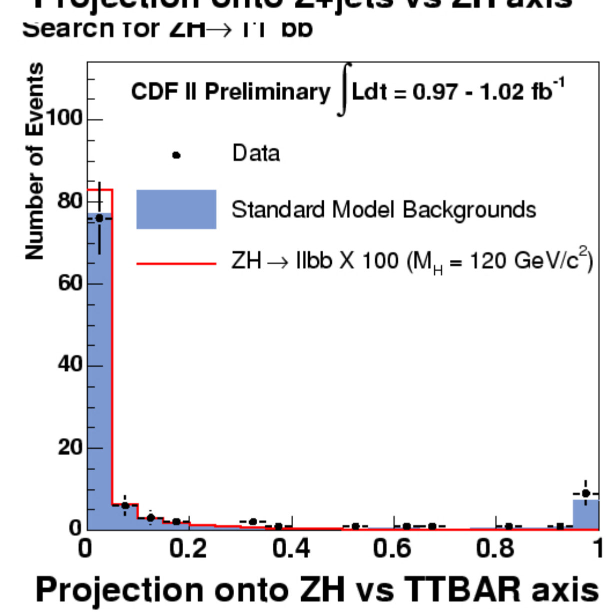


- Distribution 2d des candidats utilisée pour le calcul de limite



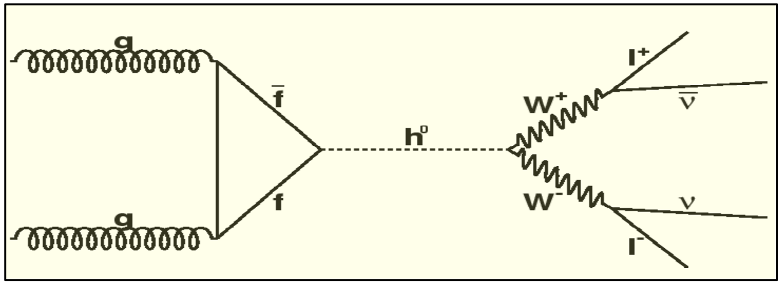
$\sigma(ZH)\times B(H\to bb) < 2.2$ pb@95%

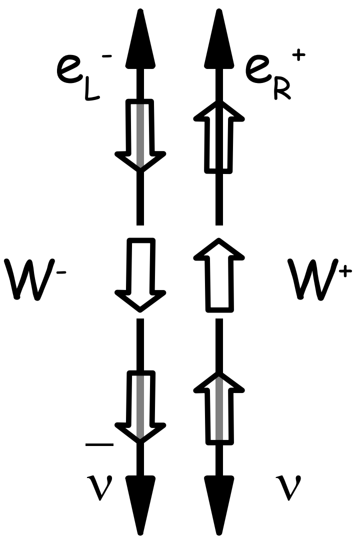
$\sigma_{95}/\sigma(SM) = 27.2$



Hautes masses

H->WW* -> llνν – Signal et bdf



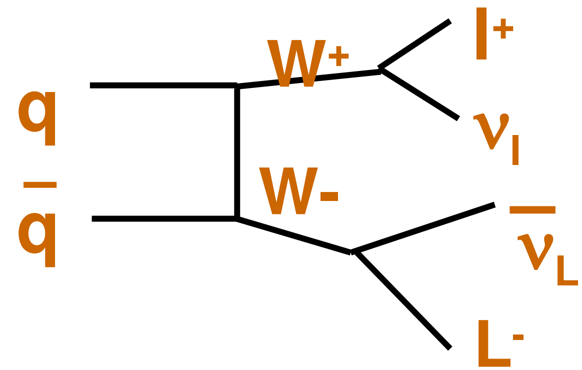


2leptons ~ 40 GeV

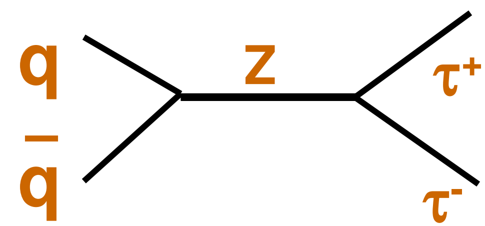
Missing E_T ~ 40 GeV

correlation de spin :

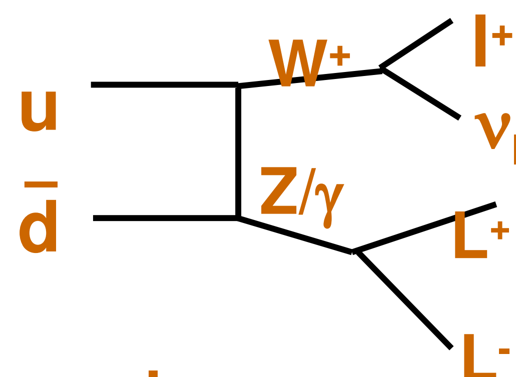
- petite masse di-leptons
- petit Δφ (l+,l-)



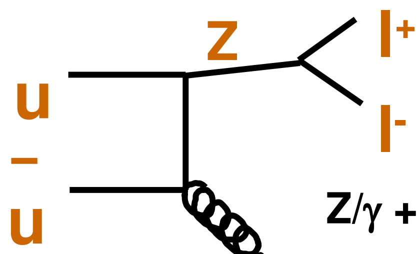
EW production WW



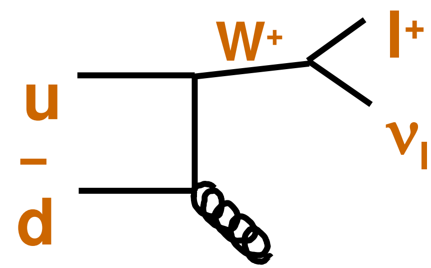
Z en ττ suivi de τ –> lνν



WZ +1 lepton non détecté



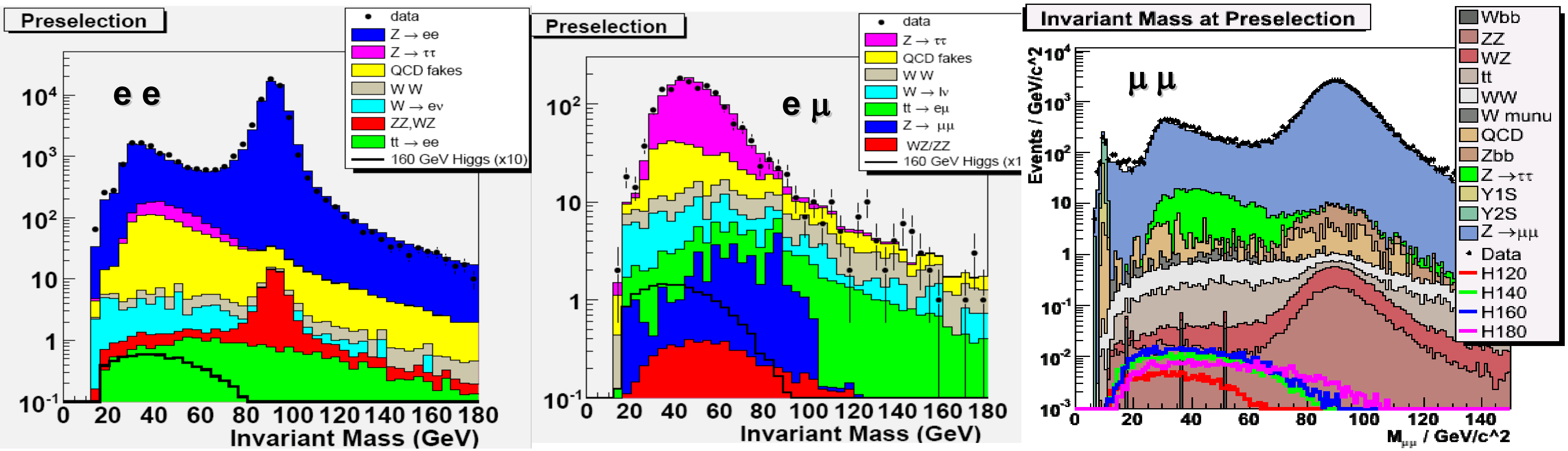
Z/γ + Jets faking MET



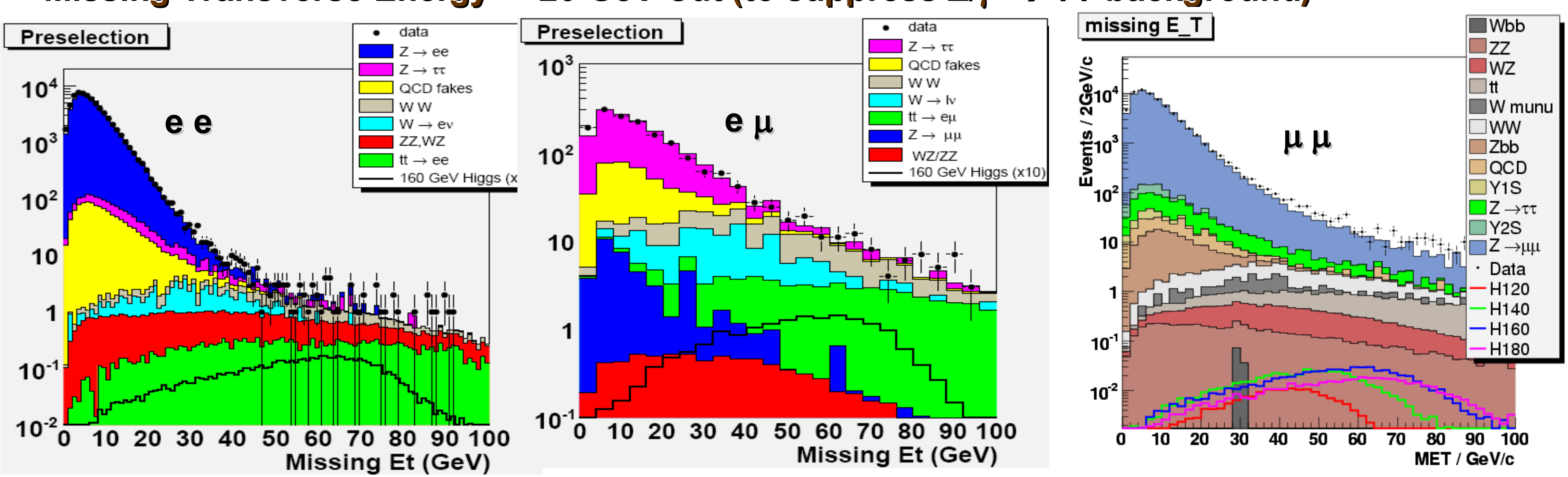
W+jet Jet faking lepton

H->WW* -> ee, eμ, μμ à D0 (950-930 pb^{-1})

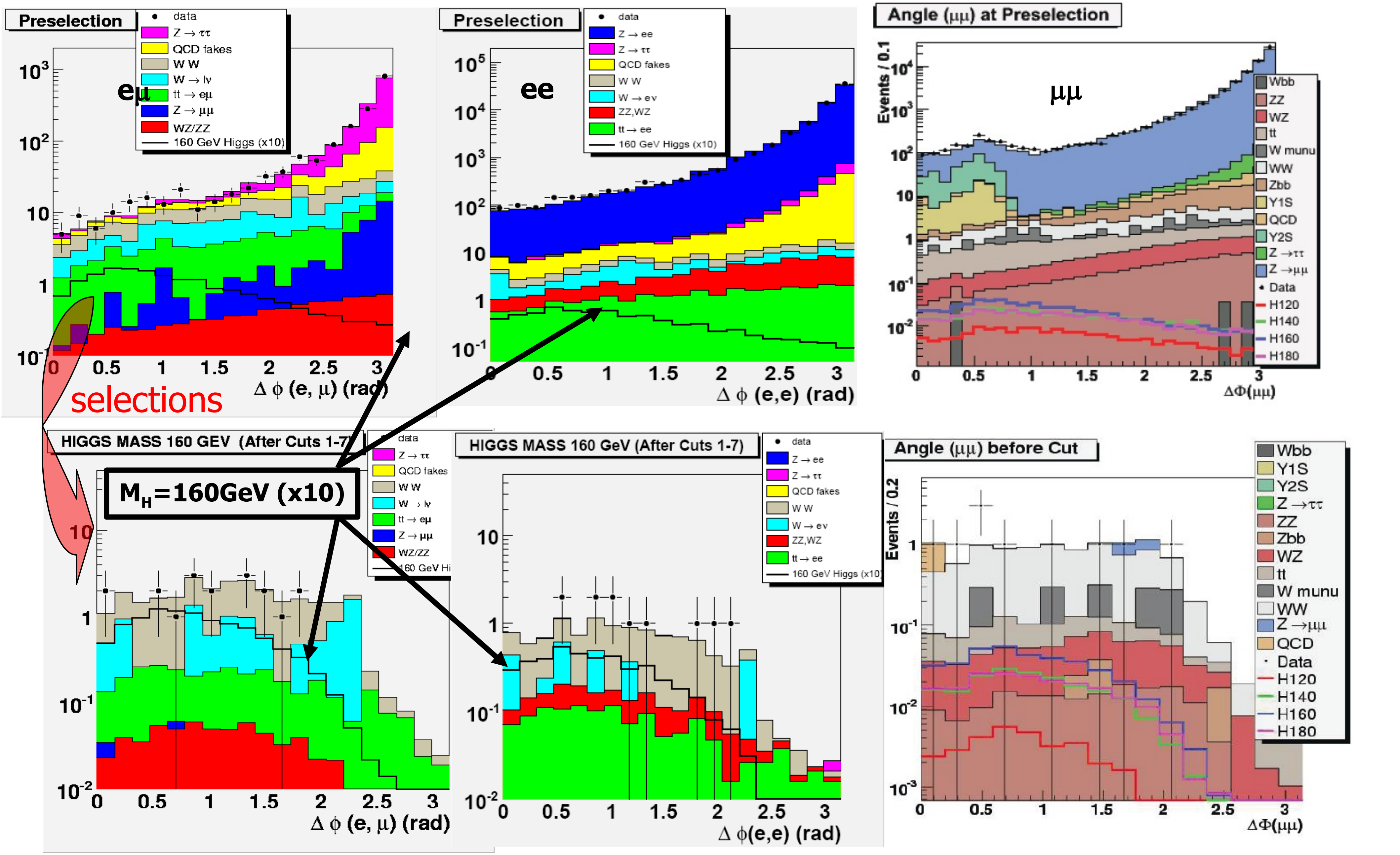
Preselection: Trigger, ID, leptons of opposite charge: p_T^{l1} = 15 GeV; p_T^{l2} = 10 GeV



Missing Transverse Energy > 20 GeV Cut (to suppress Z/γ* → l^+l^- background)



DØ : H->WW* -> ee, eμ, μμ (950-930 pb^{-1})



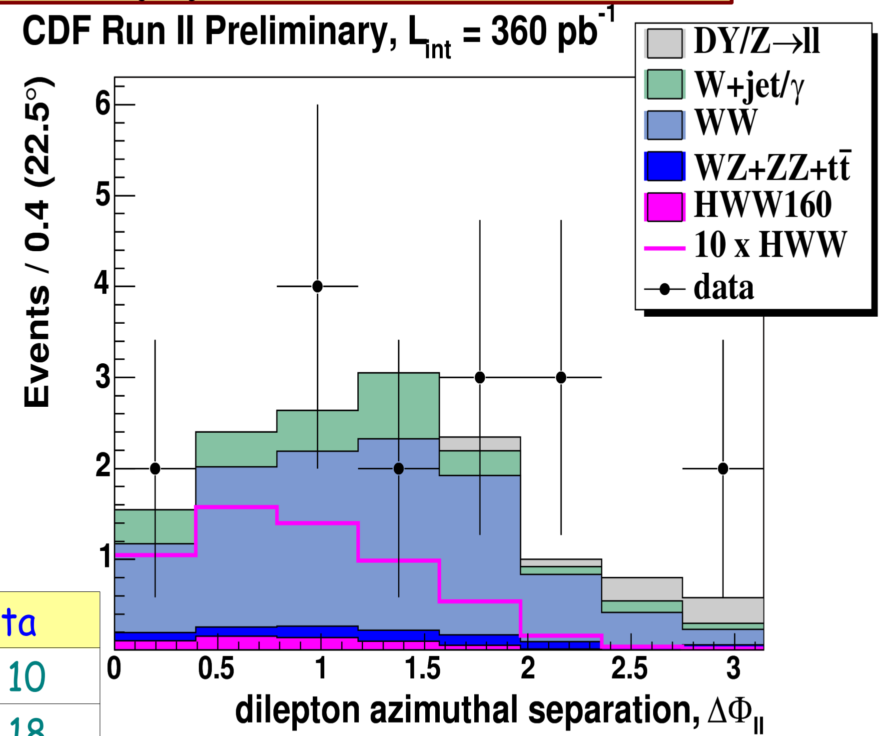
H->WW* Production (2)

CDF

- All channel together L~360 pb^{-1}
- Dilepton Mass < 0.5 x $m_{H,}$
- Fit $\Delta\phi$ (l^+l^-) distribution to derive limit

DØ

- 3 separate analysis. L~950 pb^{-1}
- $\Delta\phi(l+,l-)<2.0$



	WW	W+jet/γ	Z/γ	top	WZ/ZZ	QCD	total	Data
DØ ee	7.0±0.2	1.4±0.6	0±0	1.1±0.1	0.8±0.1	0.06±0.02	10.3±0.6	10
DØ eμ	16.4±0.1	5.3±1.5	0.02±0.01	2.1±0.1	0.6±0.1	0.1±0.05	24.4±1.5	18
DØ μμ	6.6±0.1	1.0±0.4	0.6±0.4	0.5±0.1	0.5±0.1	0.6±0.6	9.8±0.8	9
CDF l+l-	9.8±1.0	1.1±0.1	0.8±0.2	0.35±0.03	0.40±0.05	1.3±0.7	13.8±1.3	16

pour m_H=160 GeV

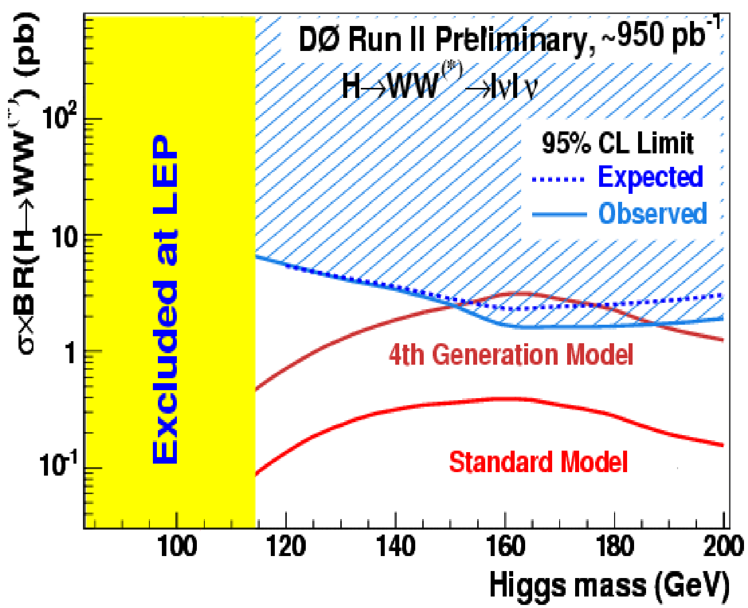
CDF :

σxB(H->WW) <3.2 pb @95%

DØ:

σxB(H->WW) <1.7 pb @95%

$\sigma_{95}/\sigma(SM)$ = 6



Combinaison

Combinaison des différents canaux

- 1ère combinaison entre CDF et D0 : été 2006.

Tevatron Higgs and New Phenomena Working Group

- Méthode statistique
  - D0 méthode « CLs » (comme au LEP) = fréquentiste « modifée »
  - CDF méthode Bayesienne
  - Les deux méthodes donnent des résultats similaires à 10% près
  - Les corrélations sur le signal et les bdf sont prises en comptes

Sytématiques à CDF

TABLE V: The breakdown of systematic uncertainties for each individual CDF analysis. All positive-signed uncertainties within a group are considered 100% correlated across channels. Values with negative signs are considered uncorrelated.

Source	$WH \rightarrow \ell\nu b\bar{b}$ ST	$WH \rightarrow \ell\nu b\bar{b}$ DT	$ZH \rightarrow \nu\nu b\bar{b}$ ST	$ZH \rightarrow \nu\nu b\bar{b}$ DT	$ZH \rightarrow \ell\ell b\bar{b}$	$H \rightarrow W^+W^-$
Luminosity (%)	6.0	6.0	6.0	6.0	6.0	6.0
b-Tag Scale Factor (%)	5.3	16.0	8.0	16.0	8.0	n/a
Lepton Identification (%)	2.0	2.0	2.0	2.0	1.4	3.0
Jet Energy Scale (%)	3.0	3.0	6.0	(1.0-20.0)	(1.6-20.0)	1.0
I(S)R+PDF (%)	4.0	10.0	4.0	5.0	2.0	5.0
Trigger (%)	0.0	0.0	3.0	3.0	0.0	0.0
$Z + h.f.$ Shape (%)	n/a	n/a	n/a	n/a	-20	n/a
Backgrounds						
W/Z+HF(I) (%)	33.0	34.0	12.0	12.0	40.0	n/a
W+HF(II) (%)	0	0	-10.0	-42.0	0	n/a
Z+HF(II) (%)	0	0	-6.0	-19.0	0	n/a
Mistag (%)	22.0	15.0	17.0	17.0	17.0	n/a
Top I (%)	13.5	20.0	12.0	12.0	20.0	n/a
Top II (%)	n/a	n/a	-2.0	-3.0	n/a	n/a
QCD (%)	17.0	20.0	-10.0	-44.0	-50.0	n/a
Diboson I (%)	16.0	25.0	12.0	12.0	20.0	11.0
Diboson I (%)	n/a	n/a	-5.0	-10.0	n/a	n/a
Others (%)	n/a	n/a	n/a	n/a	n/a	-(12.0-18.0)

Sytématiques à D0

Source	$WH \to e\nu b\bar{b}$ DT(ST)	$WH \to \mu\nu b\bar{b}$ DT(ST)	$H \to W^+W^-$, $WH \to WW^+W^-$
Luminosity (%)	6.5	6.5	6.5
Jet Energy Scale (%)	4.0	5.0	3.0
Jet ID (%)	6.8	6.8	0
Electron ID (%)	6.6	0	2.3
Muon ID (%)	0	4.9	7.7
b-Jet Tagging (%)	8.5(5.0)	8.5(5.0)	0
Background σ (%)	6.0-19.0	6.0-19.0	6.0-19.0

Source	$ZH \to \nu\bar{\nu}b\bar{b}$ DT(ST)	$ZH \to e^+e^-b\bar{b}$	$ZH \to \mu^+\mu^-b\bar{b}$
Luminosity (%)	6.5	6.5	6.5
Jet Energy Scale (%)	6.0	7.0	2.0
Jet ID (%)	7.1	7.0	5.0
Electron ID (%)	0	8.0	0
Muon ID (%)	0	0	12.0
b-Jet Tagging (%)	9.6(6.7)	12.0	22.0
Background σ (%)	6.0-19.0	6.0-19.0	6.0-19.0

Combined Higgs boson Search @ CDF

All low mass channels analyses use 1 fb^{-1} of data !

WH ($l\nu$ bb)

ZH ($\nu\nu$ bb)

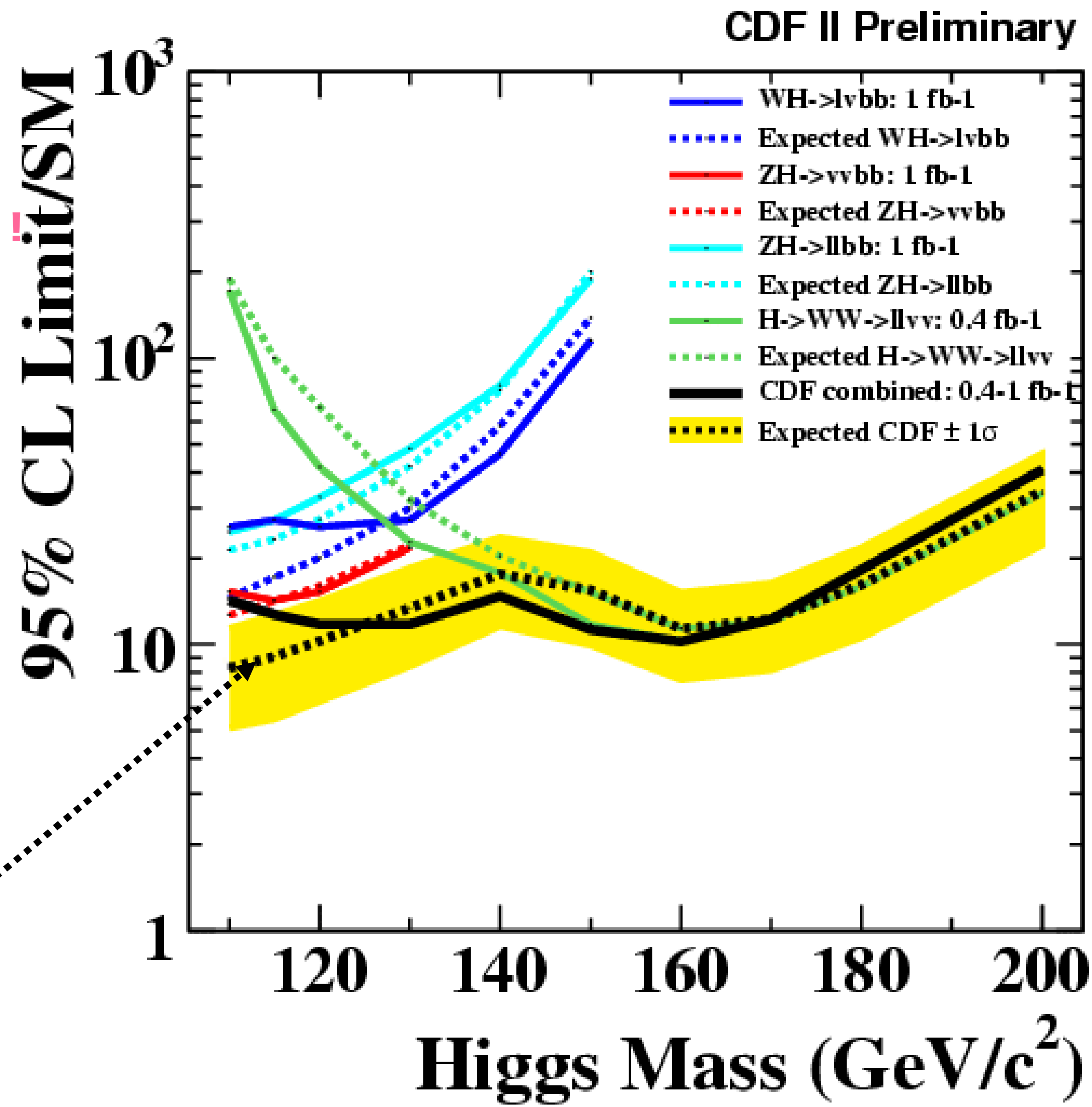
ZH (l^+l^- bb)

H→WW >~ 120 GeV

For m_H = 115 GeV, the 95%CL Limit/SM is

9 (expected)

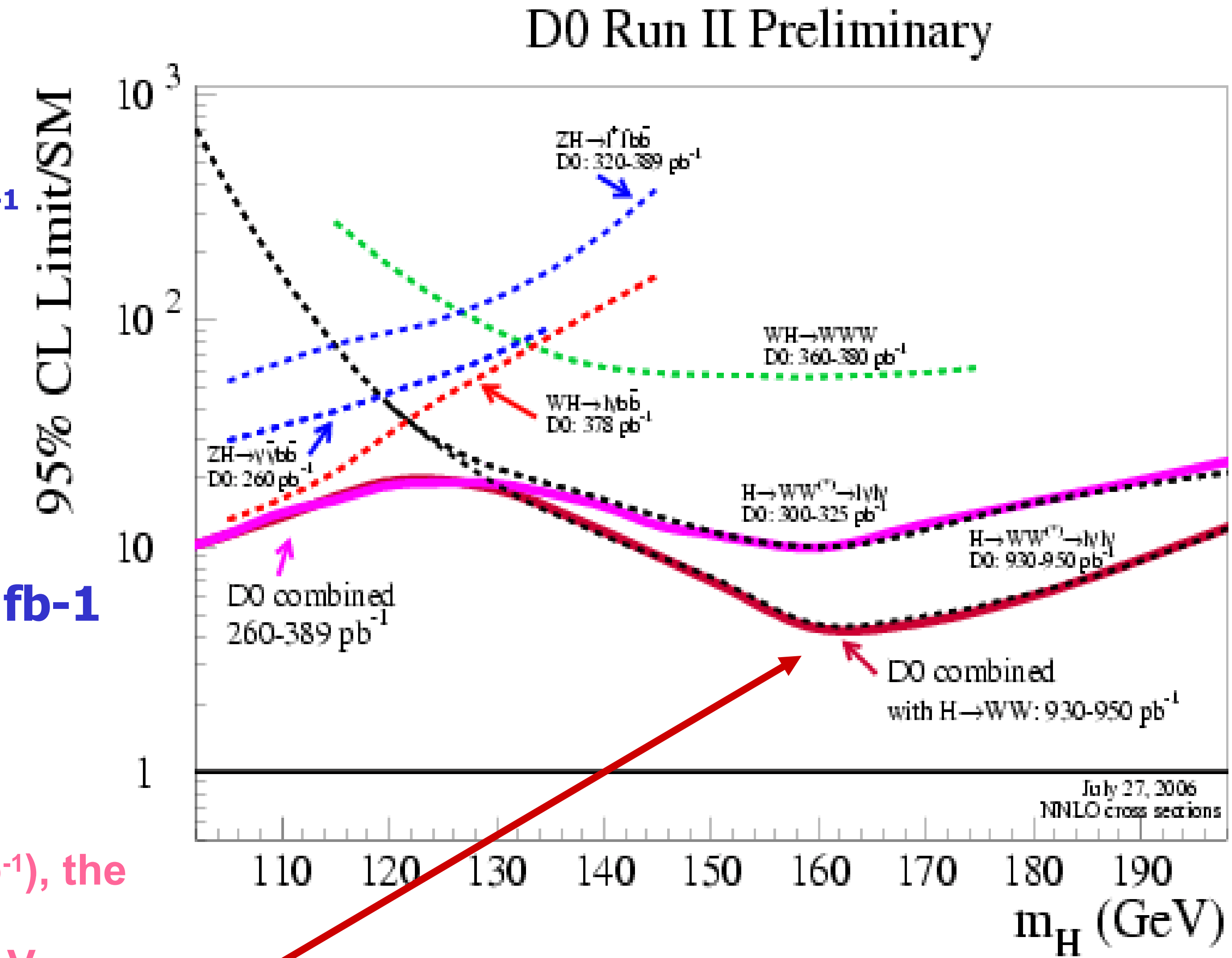
13 (observed)



Combined Higgs boson Search @ DØ

luminosity 260-390 pb^{-1}

- WH (μ) ST,DT
- WH (l) ST DT
- ZH ($\nu\nu$) ST,DT
- ZH (l^+l^-) DT
- WWW (ee,eμ,$\mu\mu$)
- WW (ee,eμ,$\mu\mu$) → 1 fb-1



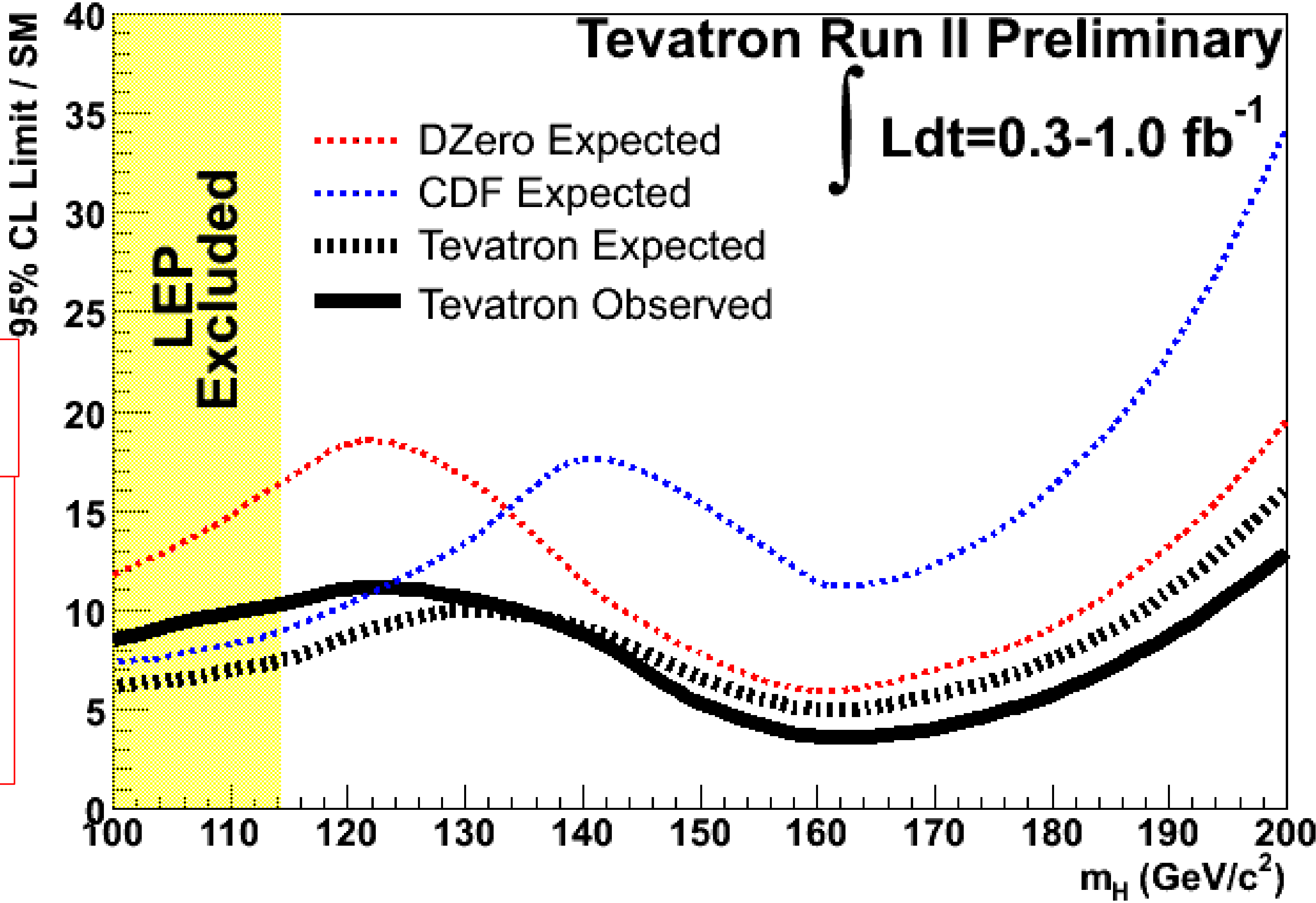
With low statistics (0.3 fb^{-1}), the cross-section factors
Data/SM = ~ 15 at 115 GeV
~ 9 at 160 GeV

With higs statistics (1 fb^{-1})
Data/SM = ~ 5 at 160 GeV

Based on our first experiences with Data, can cdf+dØ reach exclusion for a 115 GeV Higgs with 2 fb^{-1} of data, as early simulation studies were expecting ?

Tevatron SM Higgs Combination

All CDF and DØ results now combined for the first time ➔



m_H (GeV)	Limit/SM Exp.	Obs.
115	7.6	10.4
130	10.1	10.6
160	5.0	3.9
180	7.5	5.8

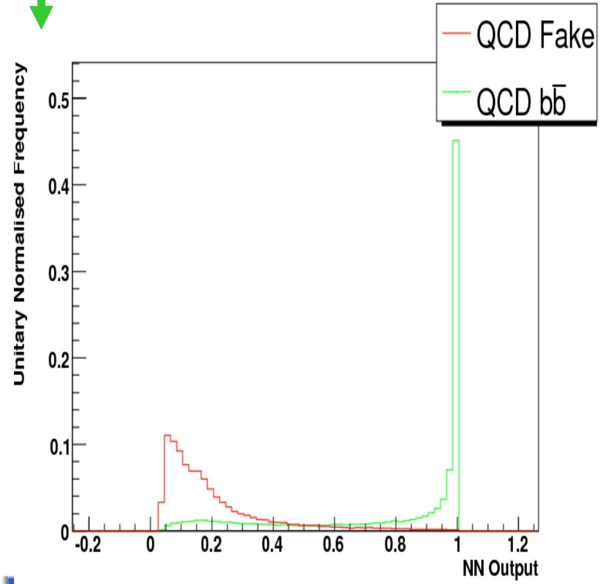
Note: the combined result is essentially equivalent to one experiment with 1.3 fb^{-1}, since both experiments have "complementary" statistics at low and high mass

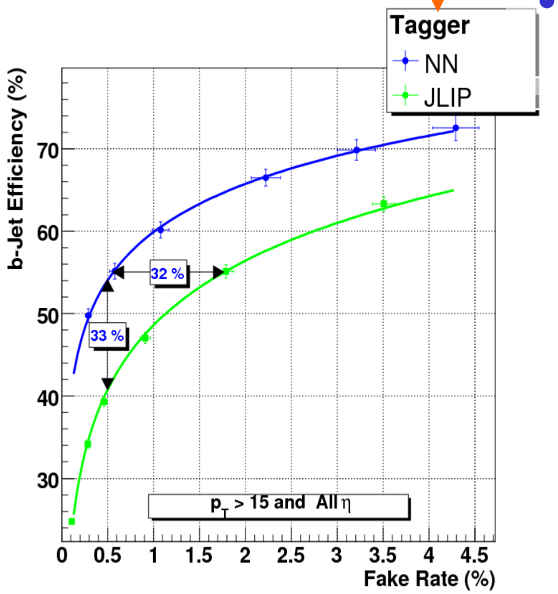
➔ we are indeed already close to the sensitivity required to exclude or "evidence" the higgs at the Tevatron

Expected improvment at D0

New b-tagging tool at DØ (bh)

- Combines various variables from the track based b-tagging tools in a Neural Network, trained on Monte Carlo
- Performance measured on data
- Substantial improvement in performance over constituent input b-taggers
- Increase of 33% in efficiency for a fixed fake rate of 0.5 %
-





- Jet energy resolution (recalibration + track-jet algorithm)
  - Subtract expected energy deposition in cal
  - Add the track momentum
  - Add the energy of out-of-cone tracks

Improve the jet energy resolution by ~20%

- Use improved calorimeter calibration
  - Z→ bb to calibrate b-jet response

- L1-cal Trigger (DØ Upgrade)
  - Important for difficult channels → efficiency improvement (ZH→ννbb, hbb)

- Addition of SMT Layer 0 (DØ Upgrade)
  - r@L1 = 2.7 cm → r@L0 = 1.6 cm
    ➔ better impact parameter resolution
  - redundancy in pattern recognition for higher luminosity reduce fake track
  - Keep performance if degradation of Layer 1 due to radiation damage

➔ further b-tag improvement (~15%)

➔ improvement on Higgs sensitivity

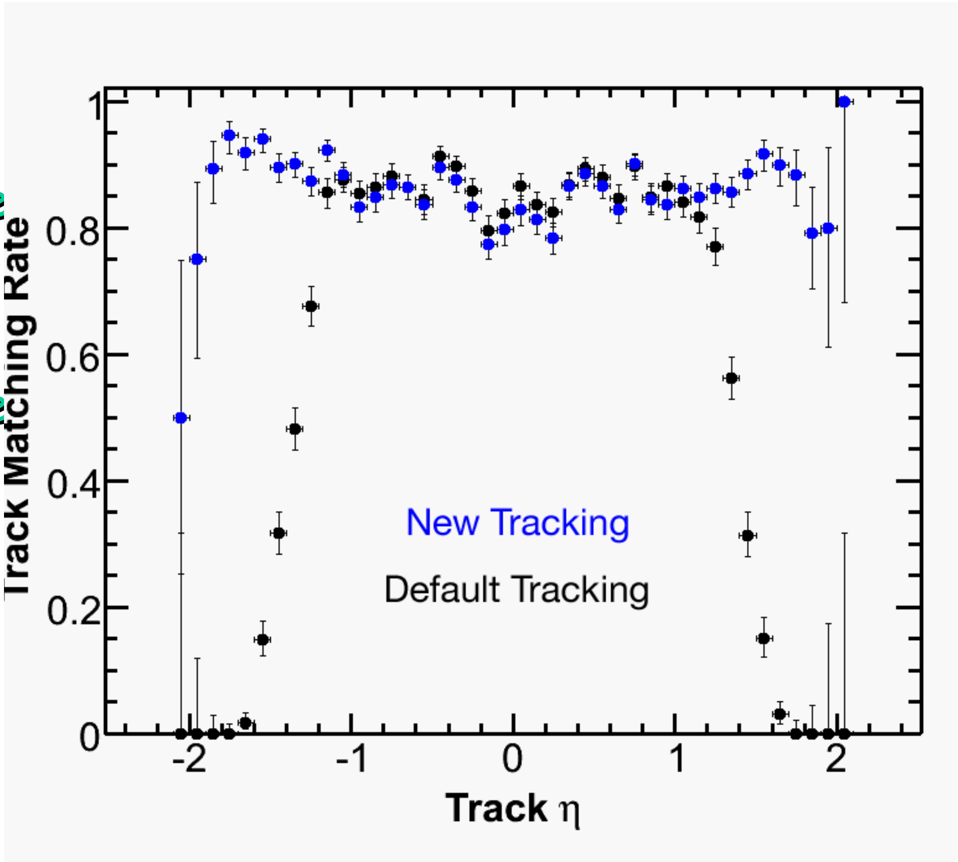
CDF: Expected Improvements

Increase acceptance

- inclusion of forward muons
- improved tracking and b-tagging in the forward region

Add additional channels:

- in the WH and WW analyses tau-leptons have not been used.



Improve jet resolution

Improve analysis techniques

- Neural Networks, better optimisation

Recent experience:

- in B_s mixing analysis a factor 4 in sensitivity was achieved just by improving analysis techniques

How does these CDF and DØ improvements translate in sensitivity?

Sensitivity Prospects extrapolated from 0.3 fb^{-1} D0 results

Will 6 times more lumi take our x-section factors at 115/160 GeV of ~15/9 down to 1?? Maybe.. with analyses improvements under work in CDF and DØ

➔ Close !

Ingredients (DØ)	Equiv Lumi gain (@115)	Xsec Factor m_H=115 GeV	Xsec Factor m_H= 160 GeV
Today with ~330 pb^{-1}	-	15	9
Lumi = 2.0 fb-1	6.0	6.1	3.7
NN b-Tagger/L0	3.0	3.5	
NN analysis selections	1.7	2.7	2.8
Dijet-mass resolution	1.5	2.2	
Increased Acceptance	1.2	2.0	2.5
New channels	1.2	1.9	2.1
Reduced Systematics	1.2	1.7	
Combine DØ and CDF (assuming similar improvements at DØ and CDF)	2.0	1.2	1.5

➔ At 115 GeV needs ~3 fb^{-1}

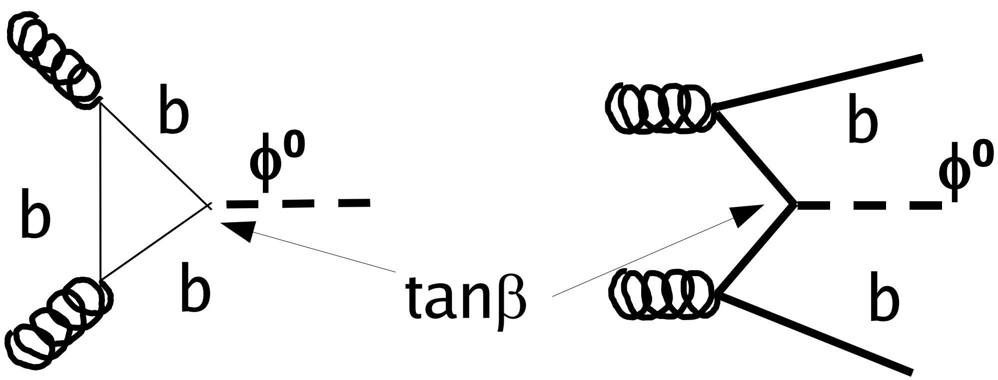
➔ At 160 GeV needs ~5 fb^{-1}

➔ 95% CL exclusion for m_H= 115-185 GeV with 8 fb^{-1}

Beyond Standard Model

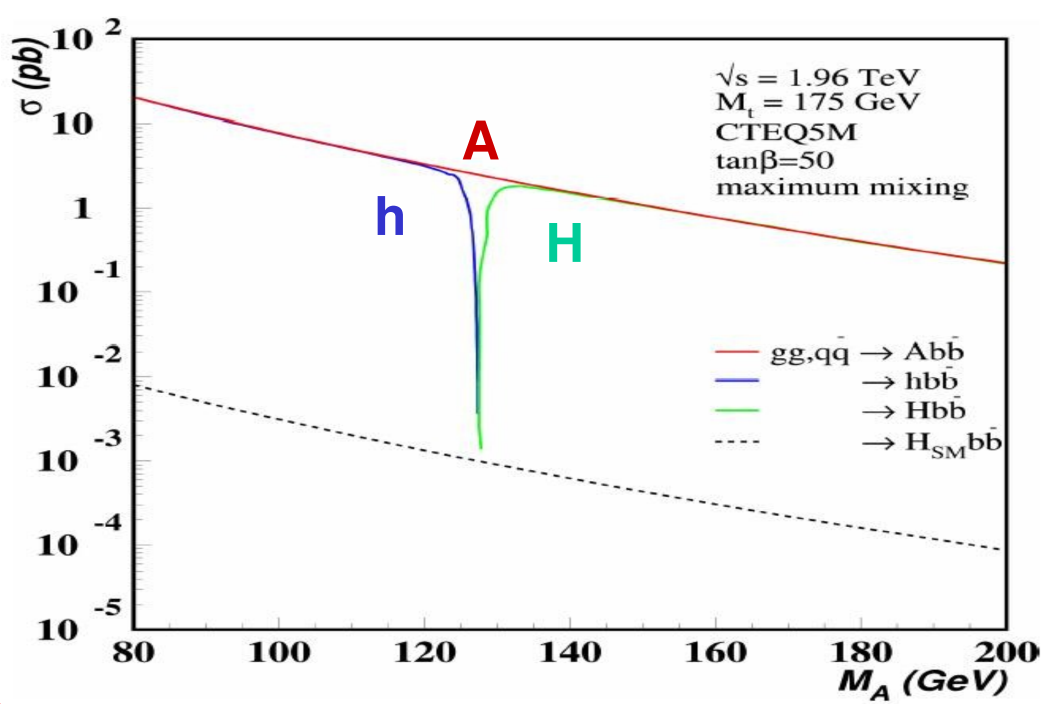
SUSY Higgs at large tan(β)

- In MSSM 2 Higgs doublets
  - tanβ= v2/v1 ratio of vev's
  - 5 Higgs : 3 neutral (h,H,A) and 2 charged (H^+,H^-)
- At large tan(β) : 2 neutral ~degenerated in mass with coupling ~tan(β)
- cross-section enhanced by $\tan^2\beta$ wrt SM
  - decays to $b\bar{b}$ (90%) or $\tau^+\tau^-$ (~10%)



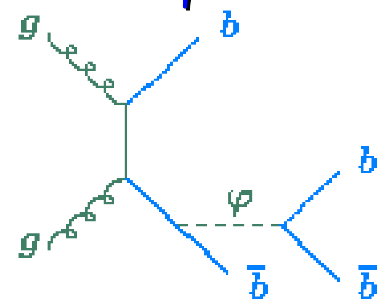
channel:
$\tau^+\tau^-$

channels:
$b\bar{b}b\bar{b}$
$b\bar{b}\tau^+\tau^-$

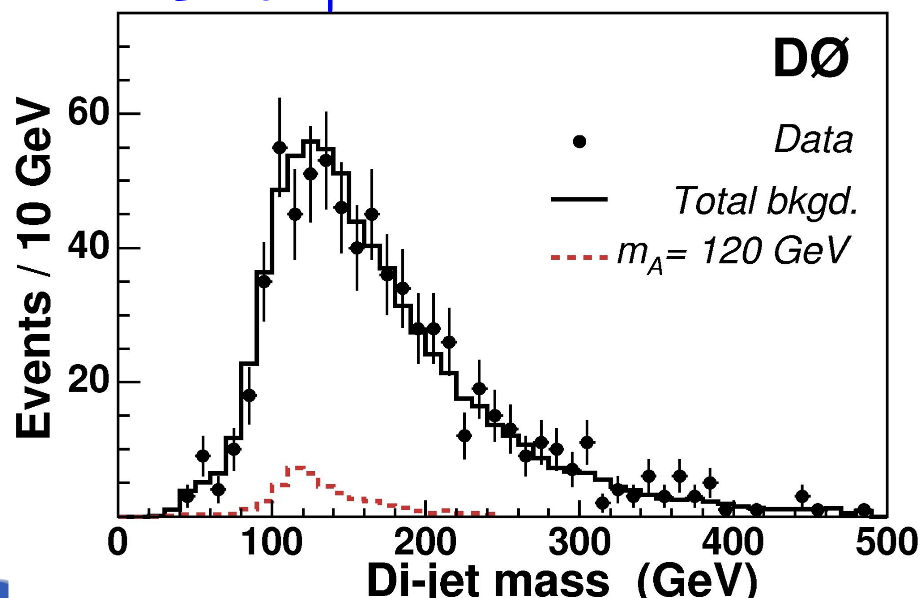


DØ: SUSY Higgs at large tan(β) (hb and hbb)

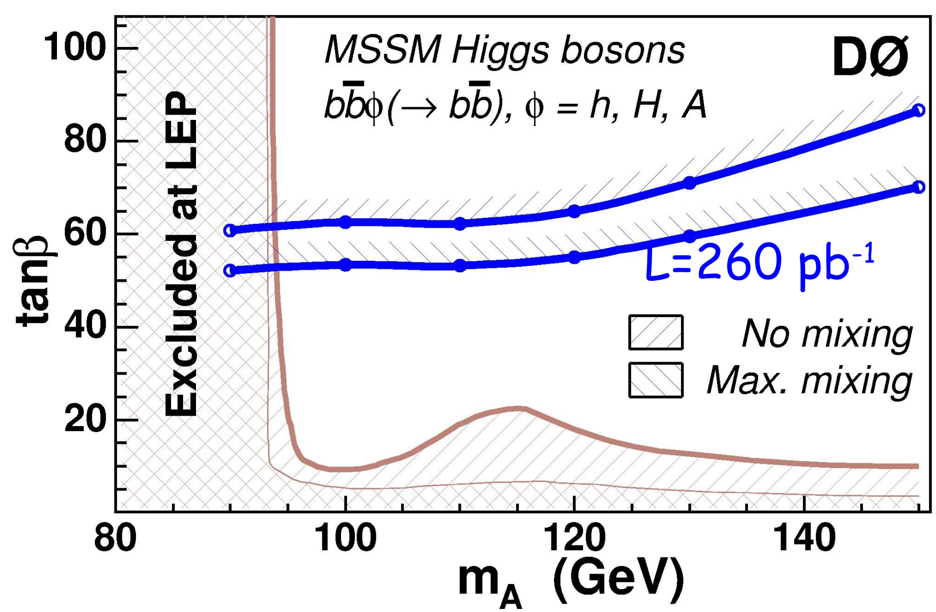
- In MSSM 5 Higgs : 3 neutral (h,H,A) and 2 charged (H^+,H^-)
  - At large tan(β) : 2 neutral almost degenerated in mass with coupling ~tan(β)
  - Enhanced production ($\sigma \sim \tan^2\beta$) of Higgs's associated with b-quarks
- Selection :
  - 3 or more jets. (E_T>45, 35, 15 GeV for m_A=100 GeV)
  - At least 3 b-tagged jets
- Efficiencies and background estimated from data



Leading jets invariant mass
L=260 pb^{-1}

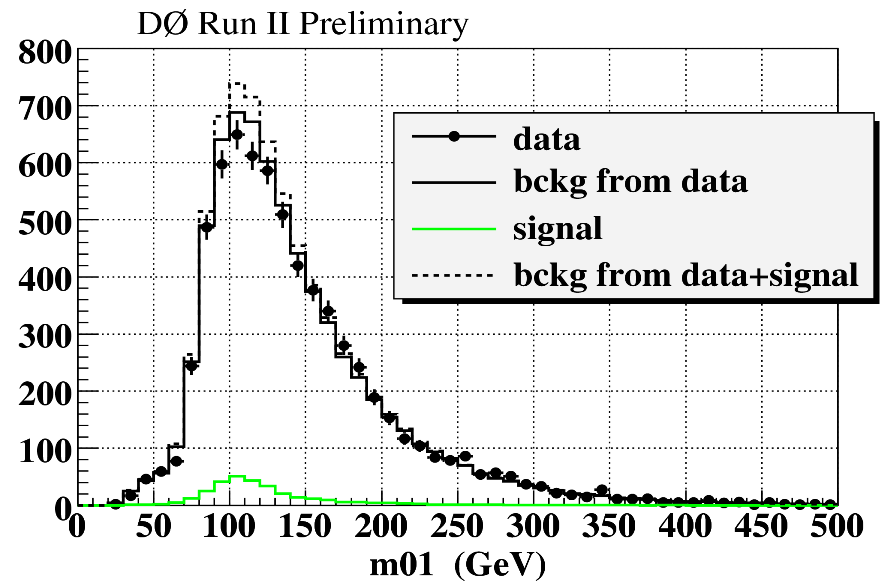


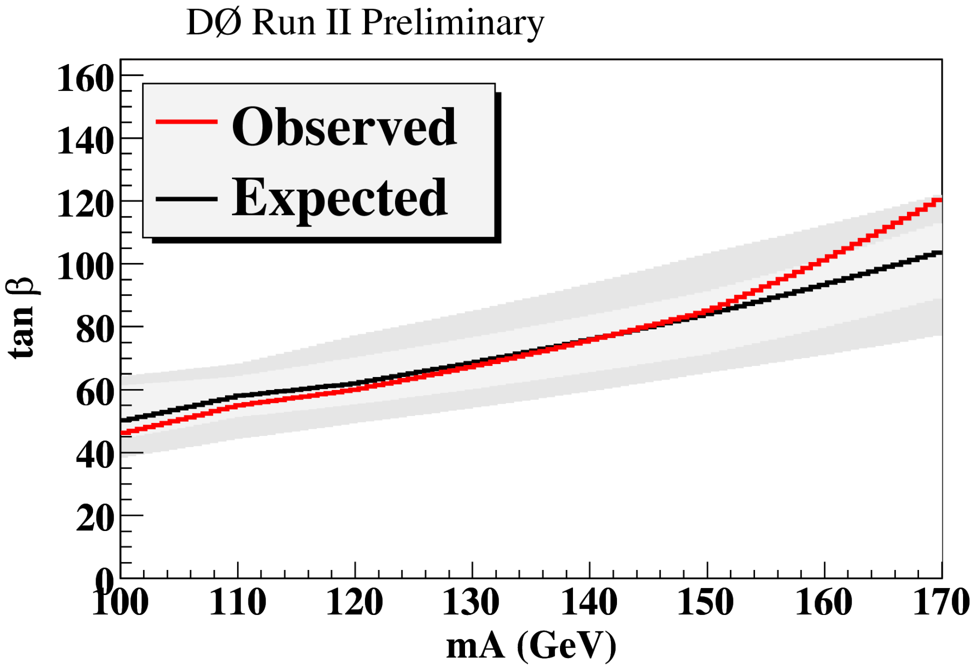
PRL 95, 151801 (2005)



DØ: SUSY Higgs at large tan(β) hbb update summer 06

- $L=900\ fb^{-1}$
- b-tagging avec réseau de neurones



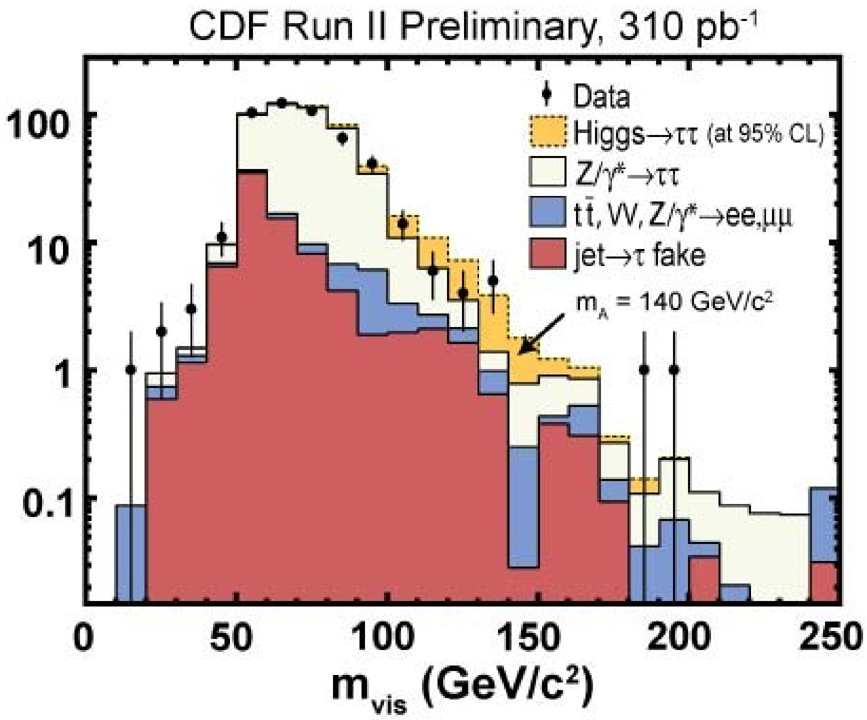


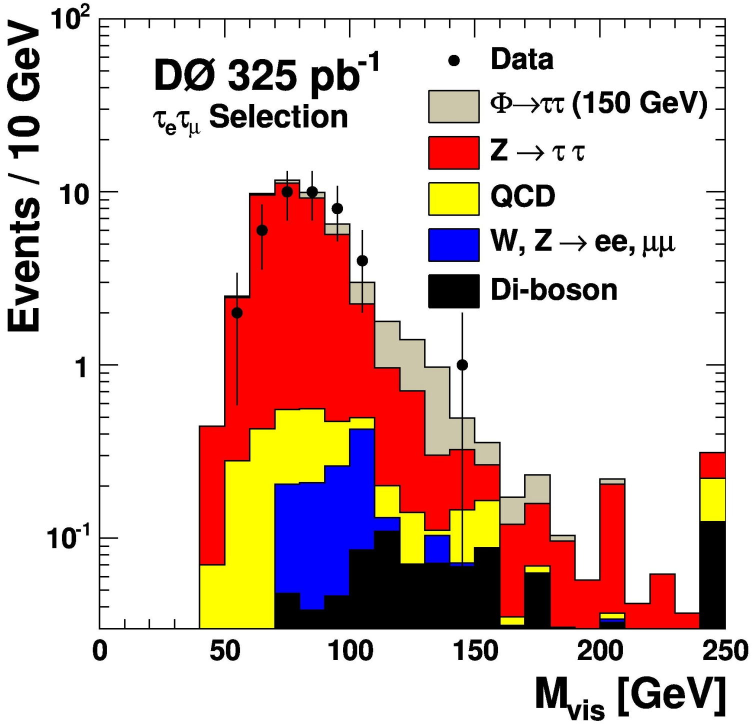
- Limites tan β ~50 proche de la zone SUSY intéressante: tanβ ~mt/mb

MSSM $\phi^0 \to \tau\tau$ at large tan(β)

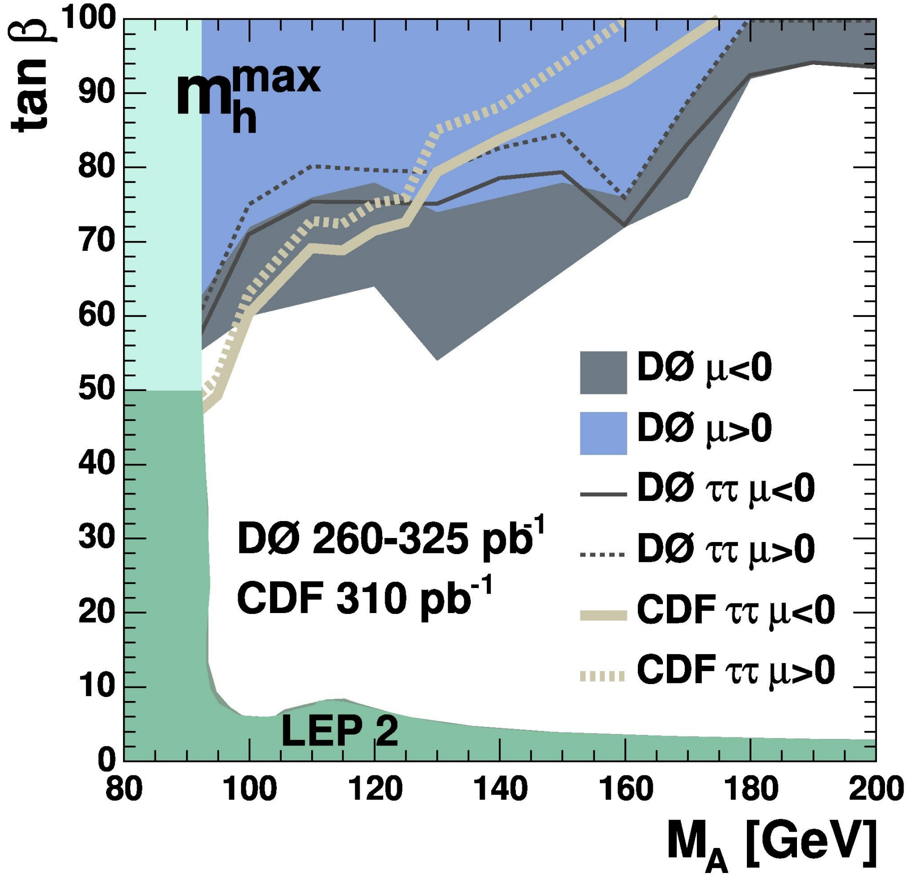
- Select $\tau_e\tau_{had}$, $\tau_\mu\tau_{had}$, and (at D0) $\tau_e\tau_\mu$ events
- Partially reconstruct Higgs via

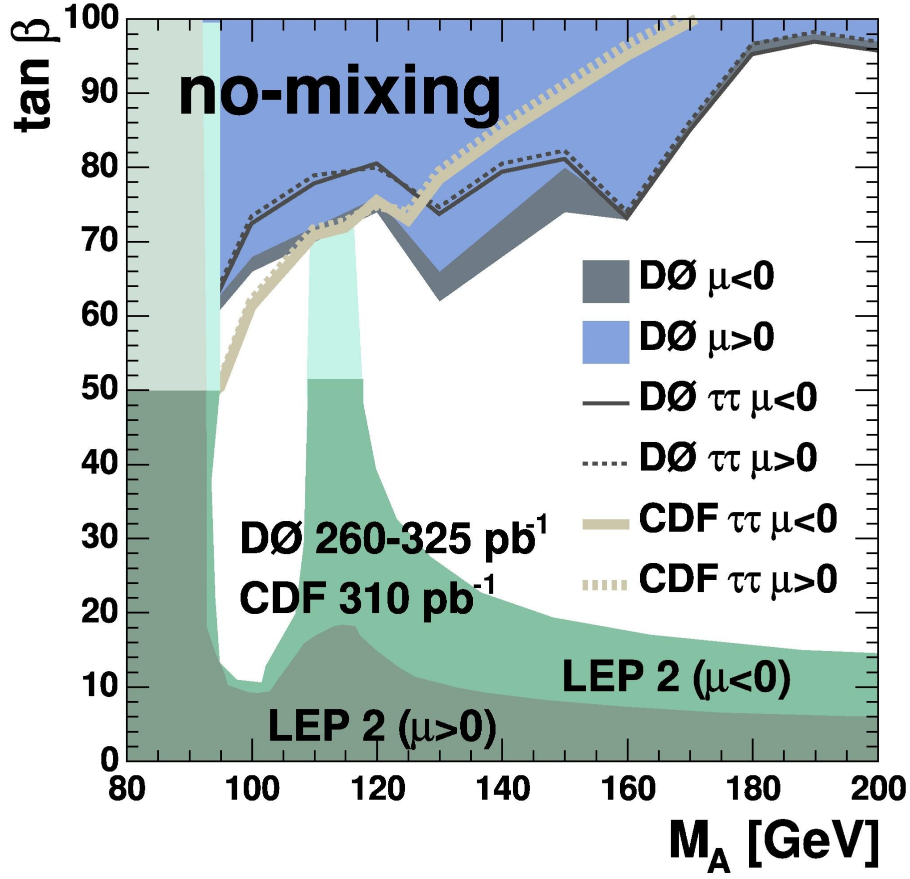
$$M_{\rm vis} = \sqrt{p_{\rm vis}^{\tau_1} + p_{\rm vis}^{\tau_2} + \not{p}_T}$$





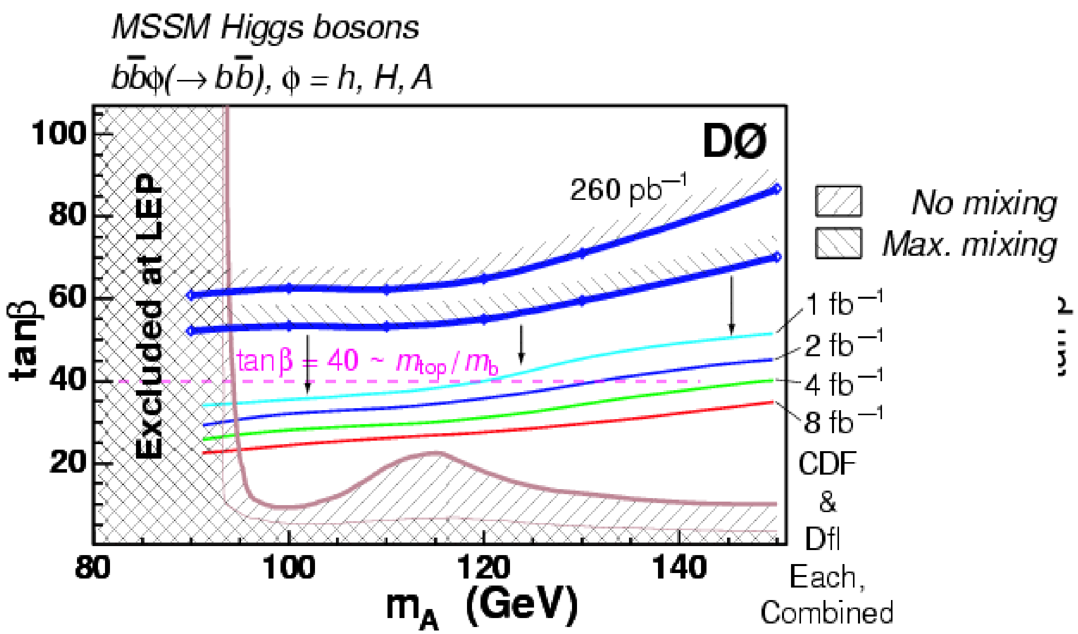
$\phi^0 \to \tau\tau$ results (comb. w/ bb)

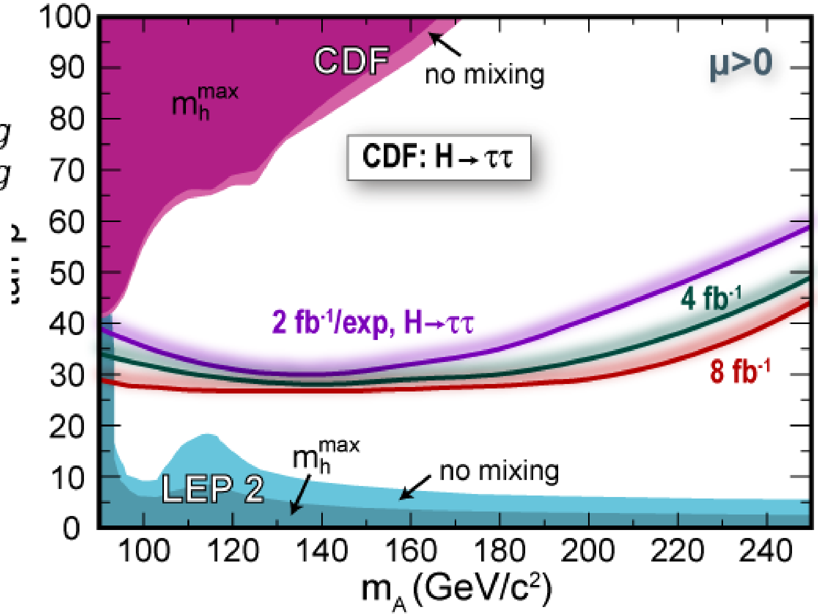




Includes bbb(b) searches

Higgs: MSSM Sensitivities

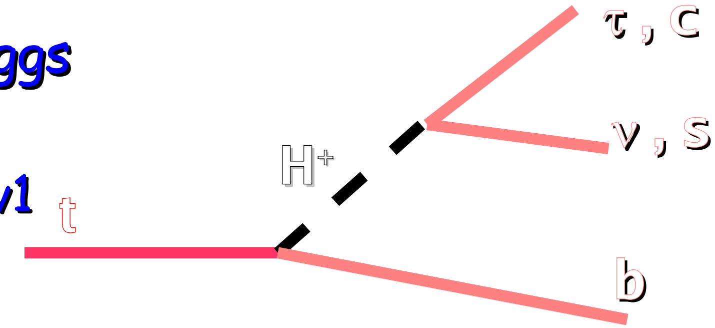




Tevatron will have sensitivity to MSSM higgs for all $\tan\beta>30$ and $M_A<200$ GeV/c^2

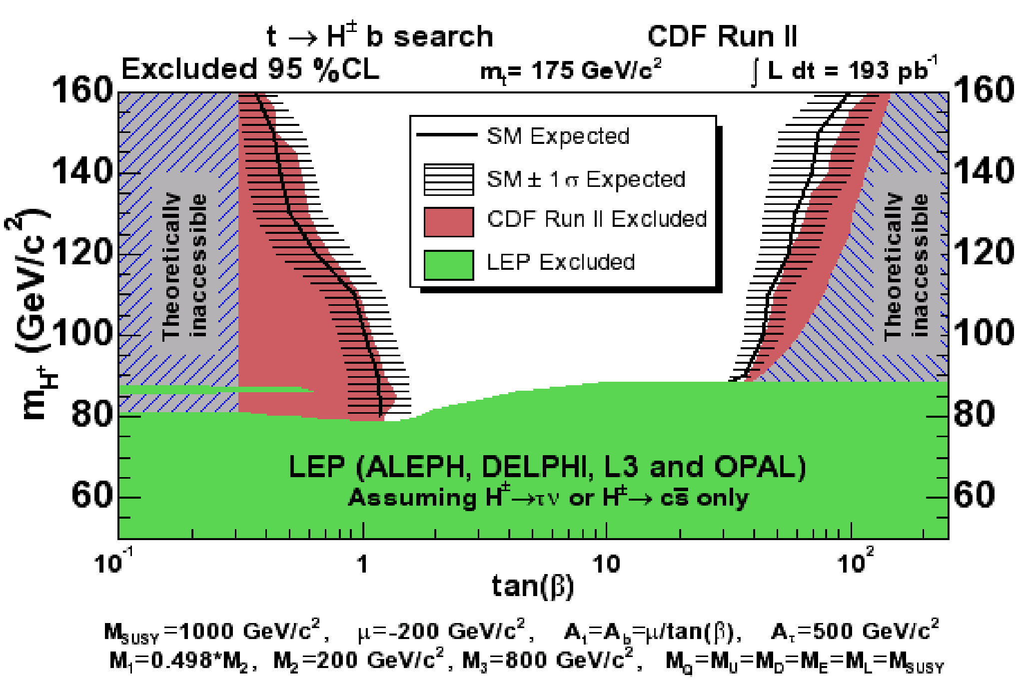
Charged Higgs in top decay

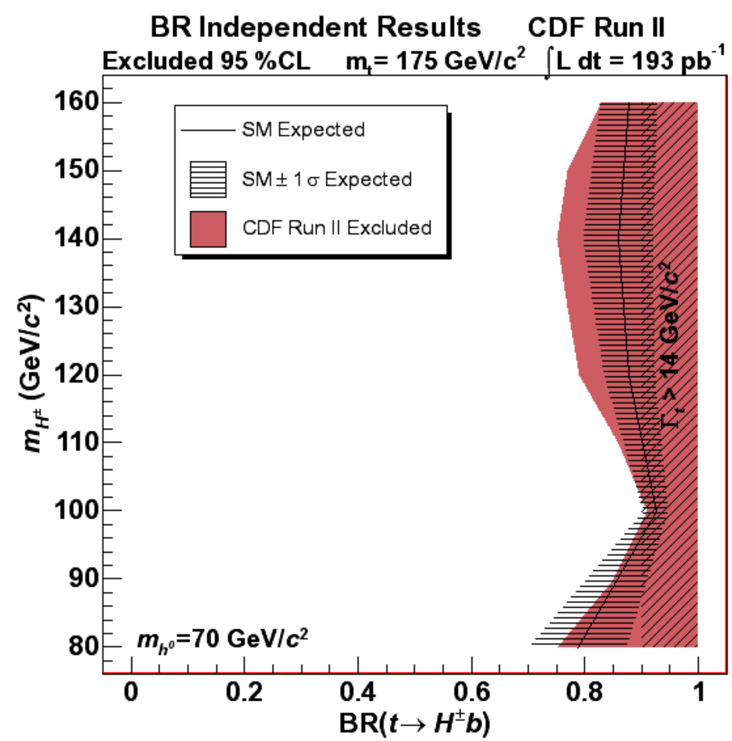
- Two Higgs doublet model predict charged Higgs
  - eg MSSM
  - Couplings to fermions: function of $\tan\beta = v2/v1$



- Possible decays in MSSM:
  - $H^+ \to \tau\nu$, cs, t^*W^+, $W^+ h^0 \to W^+bb$ Br depend upon $\tan\beta$
  - excess/deficit wrt to expectations in lepton+jets, di-lepton, τ+jets, single/double b-tag channels

CDF: PRL 96,042003



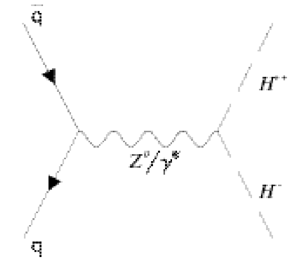


example of MSSM benchmark scenario

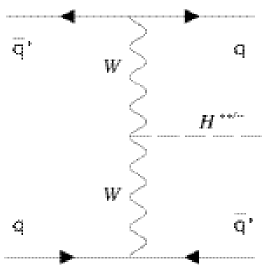
model independent limit

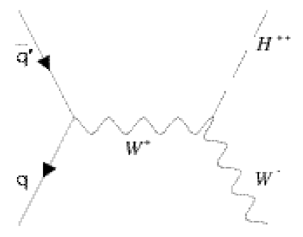
CDF, DØ: Doubly charged Higgs

- H^{++}/H^{--} decaying to two leptons are predicted
  - in model with L,R symmetry
  - models with Higgs triplet



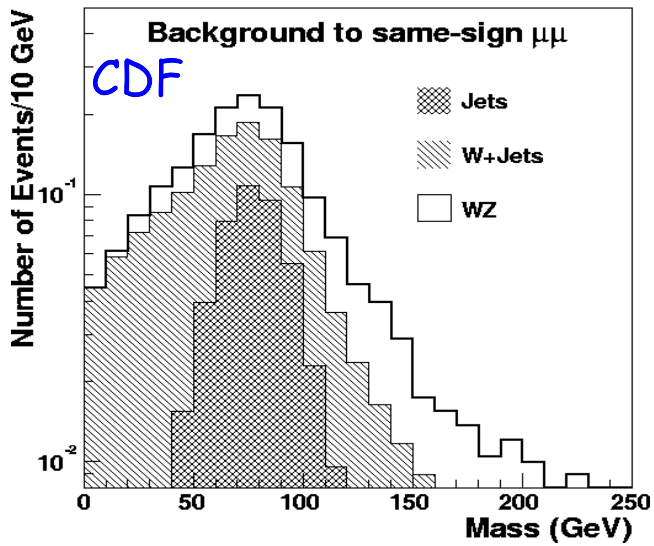
- Selection
  - one pair of same charged leptons, isolated
  - High p_T
  - With invariant mass $M_{l^+l^+} \sim M_{H^{++}}$





- Dominant Backgrounds :
  - WZ
  - W+jets
  - QCD with leptons (Heavy Flavour)
  - Drell Yan with photon conversion for ee

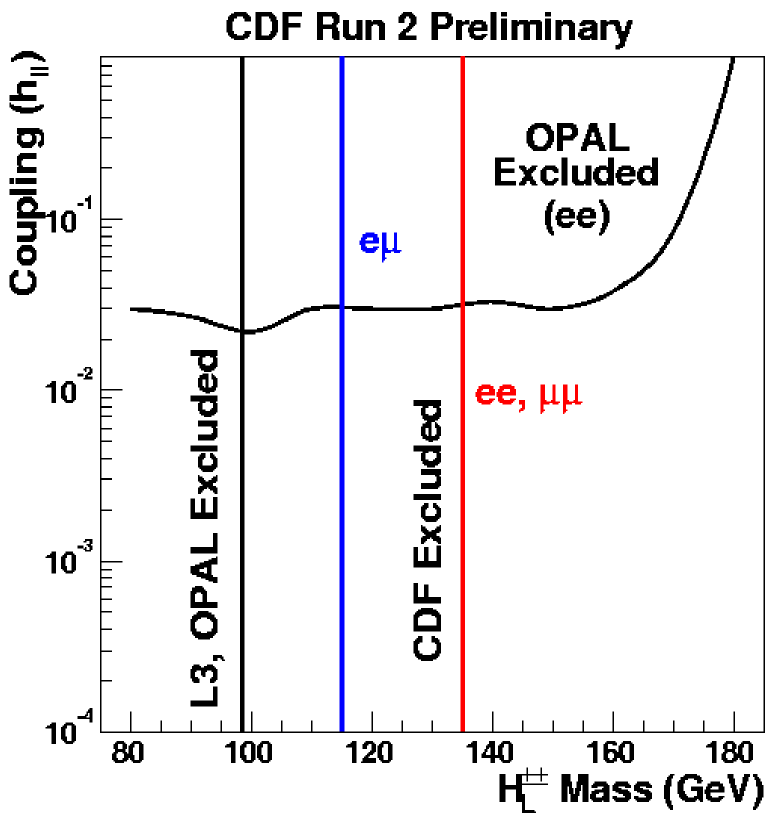
	CDF M_{ll}>80 GeV 240 pb^{-1}		DØ 106 pb^{-1}	
	Bkg	Data	Bkg	Data
ee	1.8±0.8	0		
μμ	0.8±0.6	0	1.5±0.4	3
eμ	0.9±0.4	0		



CDF, DØ: Doubly charged Higgs (2)

- 95% CL limit in (L,R) symmetric models

Mass Limit	CDF 240 pb^{-1}		DØ 106 pb^{-1}	
	H_L^{++}	H_R^{++}	H_L^{++}	H_R^{++}
ee	135	~102-113		
μμ	135	113	116	95
eμ	115			



Conclusions

Higgs standard

- Tous les canaux (sauf τs) ont été analisés avec ~ $1fb^{-1}$
- Les outils de combinaison CDF D0 sont en place
- Optimisations et améliorations
  - Certaines dejà obtenues (NN, NN b-tagging, combinaisons ST- DT)
  - En cours et futures (résolution en énergie, NN, acceptance à grand η)
- La recherche de Higgs est difficile mais si tous se passe bien, le Tevatron devrait explorer un domaine de masse intéressant pour l'exclusion et peut-être avoir une première évidence...........
- Un scénario probable:
  - Les premiers résultats LHC seront combinés avec ceux du Tevatron

MSSM

- Une zone intéressante des grands tan(β) (50-30) commence à être explorer

Support slides

Tau Identification at D0

Tau = narrow isolated jet with low track and π^0 multiplicity

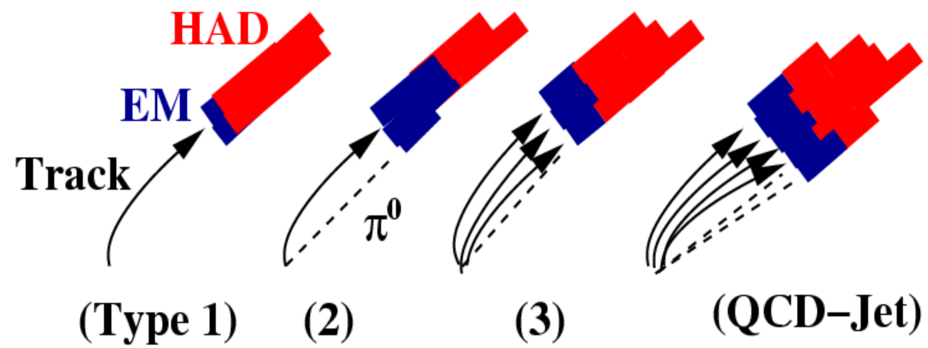
- Tau candidates are divided into 3 types:
  - Type 1: one track, calorimeter cluster without EM subcluster
  - Type 2: one track, calorimeter cluster with EM subclusters
  - Type 3: 2 or 3 tracks consistent with tau mass, calorimeter cluster

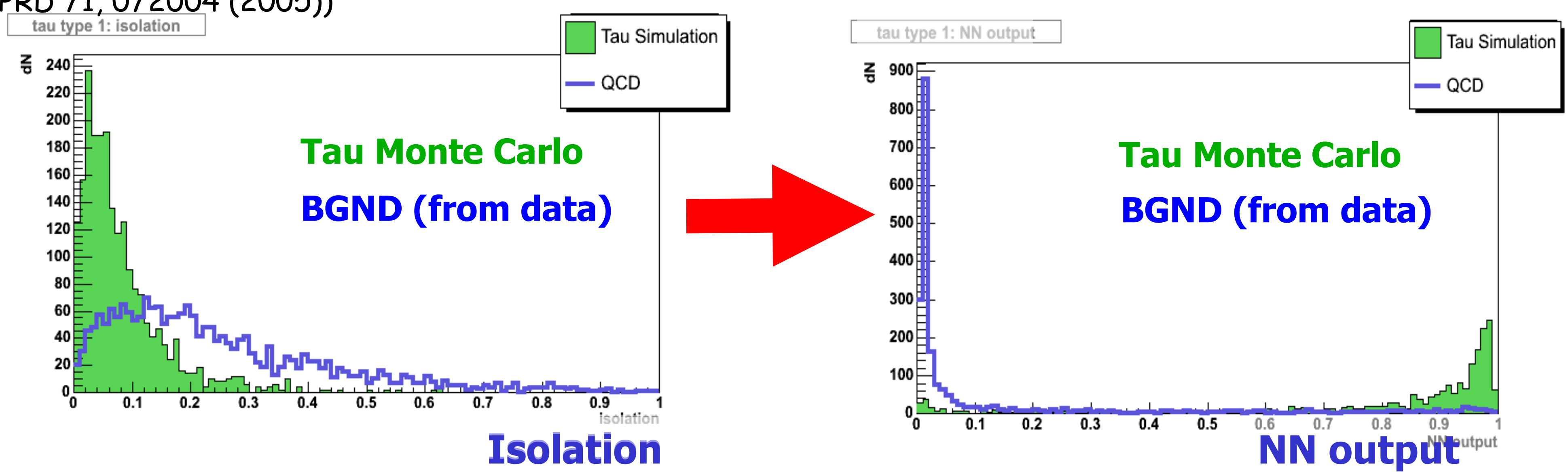
Tau identification is based on Neural Network

Non-linear correlations between variables are taken into account

Discriminating variables: Profile, Isolation, ...

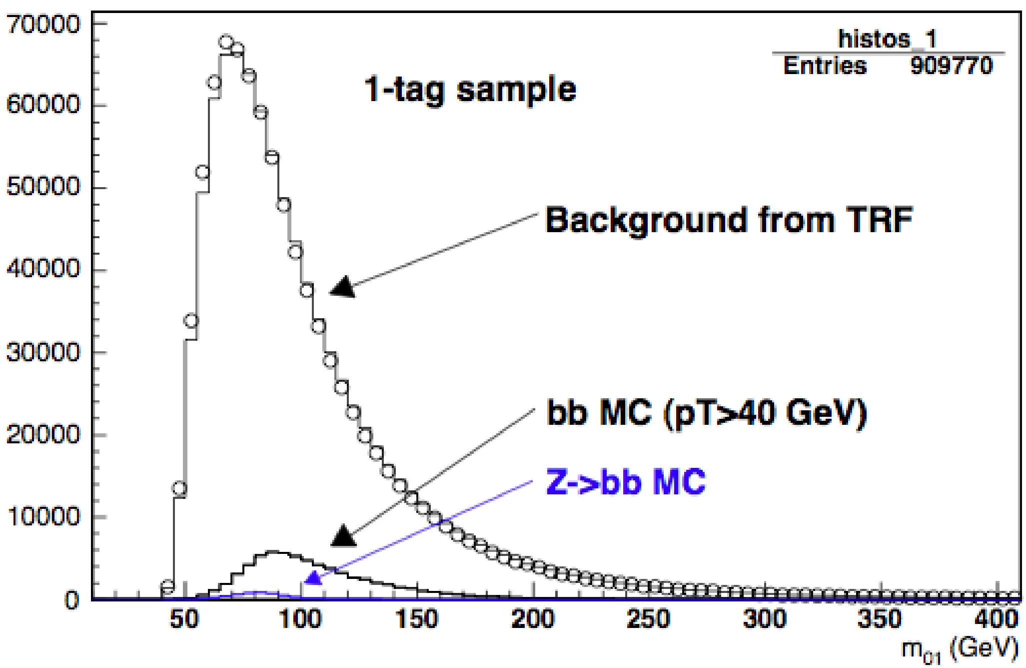
Used for cross section measurement $Z \rightarrow \tau\tau$ (PRD 71, 072004 (2005))

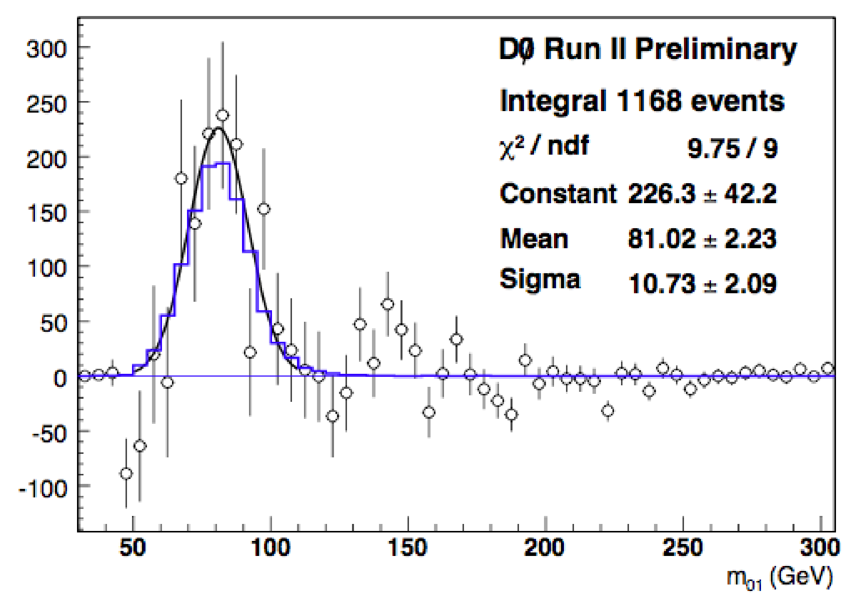




Identifying bb resonances : D0

- Z-> bb
  - H->bb benchmark
  - Can be used to determine b-jet energy scale
  - New D0 analysis finds evidence for Z->bb in dijet data
    - Background derived from data
    - 1168 Events in peak (300 pb^{-1})
    - M_Z = 81.0 ± 2.2 GeV measured
      - 83 ± 2 GeV expected (from MC)





Combining Higgs boson Searches

CDF uses a Bayesian approach

- Use Bayesian posterior probability
- Assume flat prior density for the number of Higgs events

- Combined Binned Poisson Likelihood:

$$\mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) = \prod_{i=1}^{N_C} \prod_{j=1}^{Nbins} \mu_{ij}^{n_{ij}} e^{-\mu_{ij}}/n_{ij}!$$

- Combined Posterior Density Function:

$$p(R|\vec{n}) = \int d\vec{s} \int d\vec{b} \mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) \times s_{tot} / \int dR \int d\vec{s} \int d\vec{b} \mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) \times s_{tot}$$

DØ uses the CLs (LEP) Method

the CL_S confidence interval is a normalization of CL_{S+B}

CL_{S+B} = signal + bkgd hypothesis, CL_B = bkgd only hypothesis

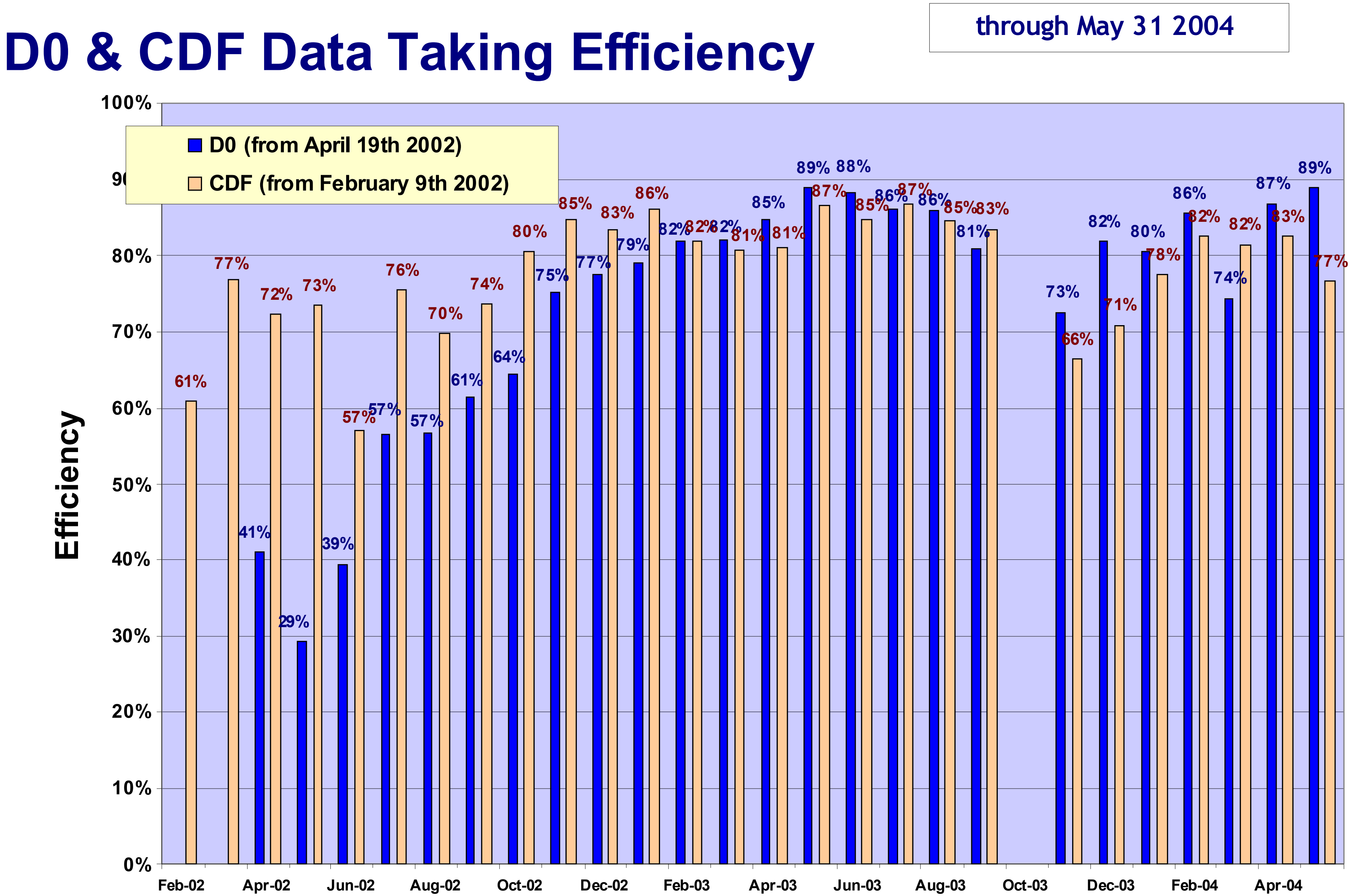
$CL_S = CL_{S+B}/CL_{B}$: CL_{S+B} & CL_B are defined using a "test statistic"

Test statistic used is the Log-Likelihood Ratio (LLR=-2 ln Q)

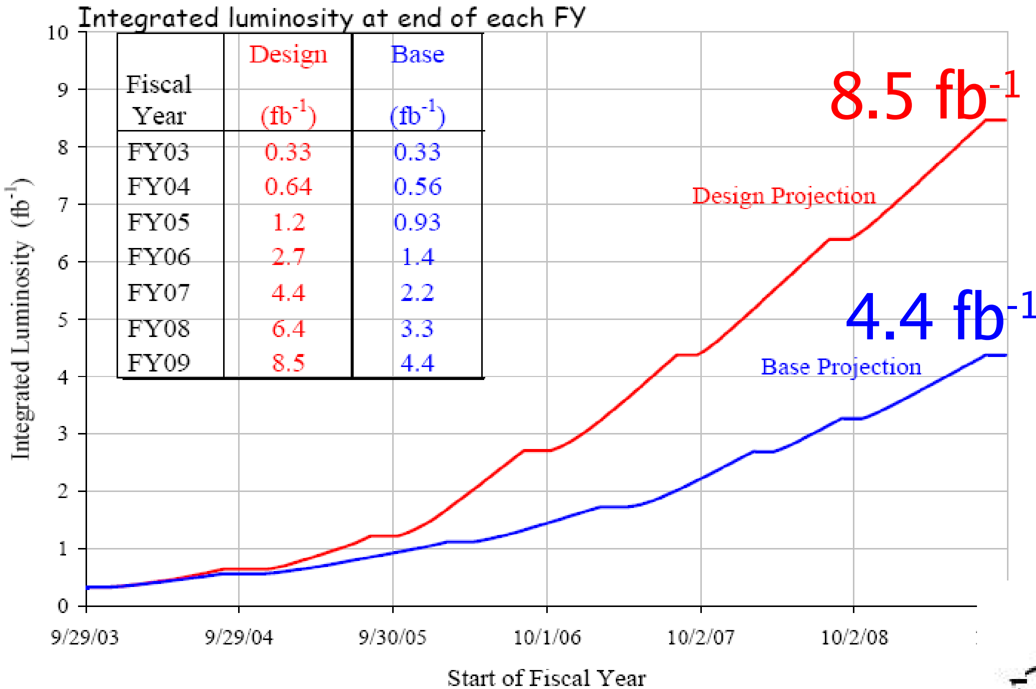
generated via Poisson statistics **($Q=e^{-(s+b)}(s+b)^d/e^{-b}b^d$) s,b,d=sig.,bkd,data)**

Tevatron Higgs combination is done with both methods
→ they give results compatible within 10%.

Monthly efficiency D0 - CDF



Higgs prospects vs luminosity prospects



Fiscal Year	Design (fb^{-1})	Base (fb^{-1})
FY03	0.33	0.33
FY04	0.64	0.56
FY05	1.2	0.93
FY06	2.7	1.4
FY07	4.4	2.2
FY08	6.4	3.3
FY09	8.5	4.4

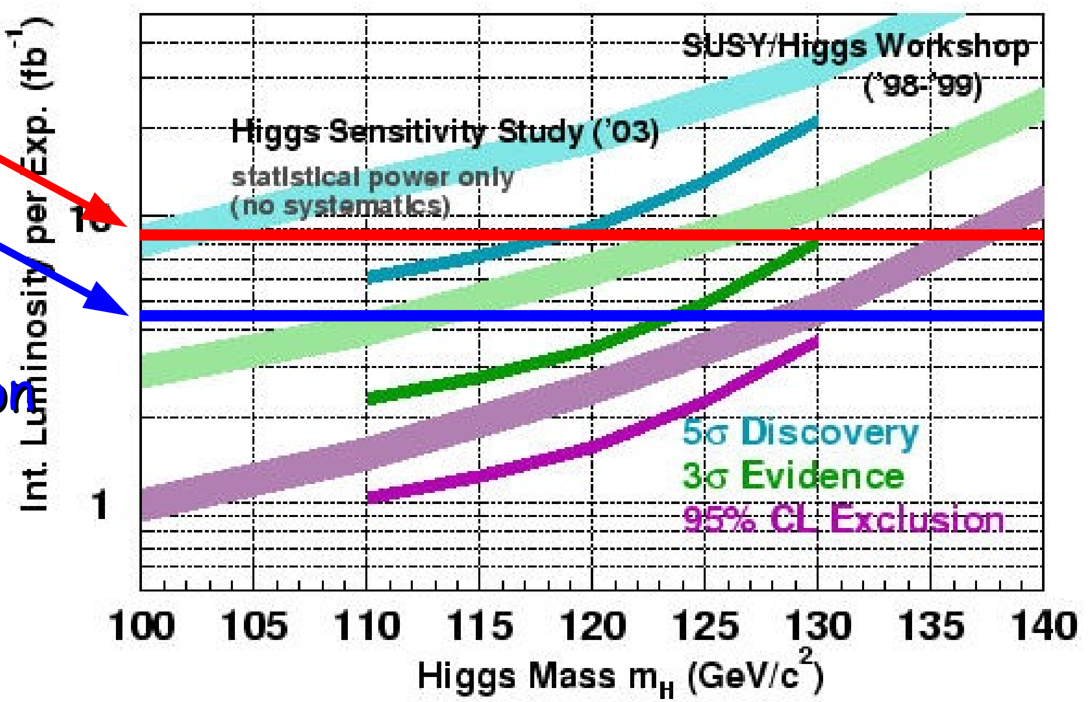
- Design projection = challenging
  - 8.5 fb^{-1} by end of 2009
- Base projection= conservative
  - schedule slippage
  - under-performance

  4.4 fb^{-1} by end of 2009

Tevatron Higgs Sensitivity Study 2003

2009 8.5 fb^{-1}

2009 4.4 fb^{-1}



- Base projection

Range 115-130 covered for exclusion

3σ evidence up to ~125 GeV.

- Design projection

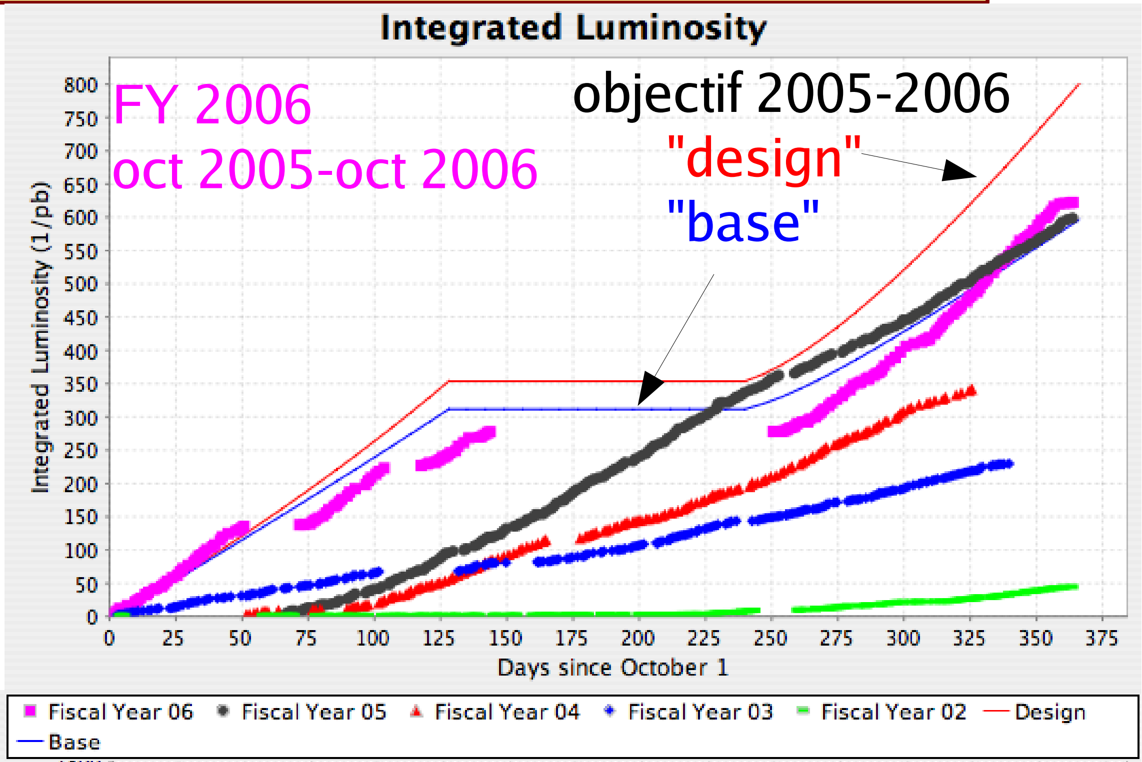
3σ evidence up to 130 GeV

5σ discovery up to 120 GeV

luminosité

Pour 2005-2006

- Objectif « design » non tenu
  - dus à des mini-shutdown plutôt qu'à des problèmes de performance
  - la luminosité instantanée excède le design

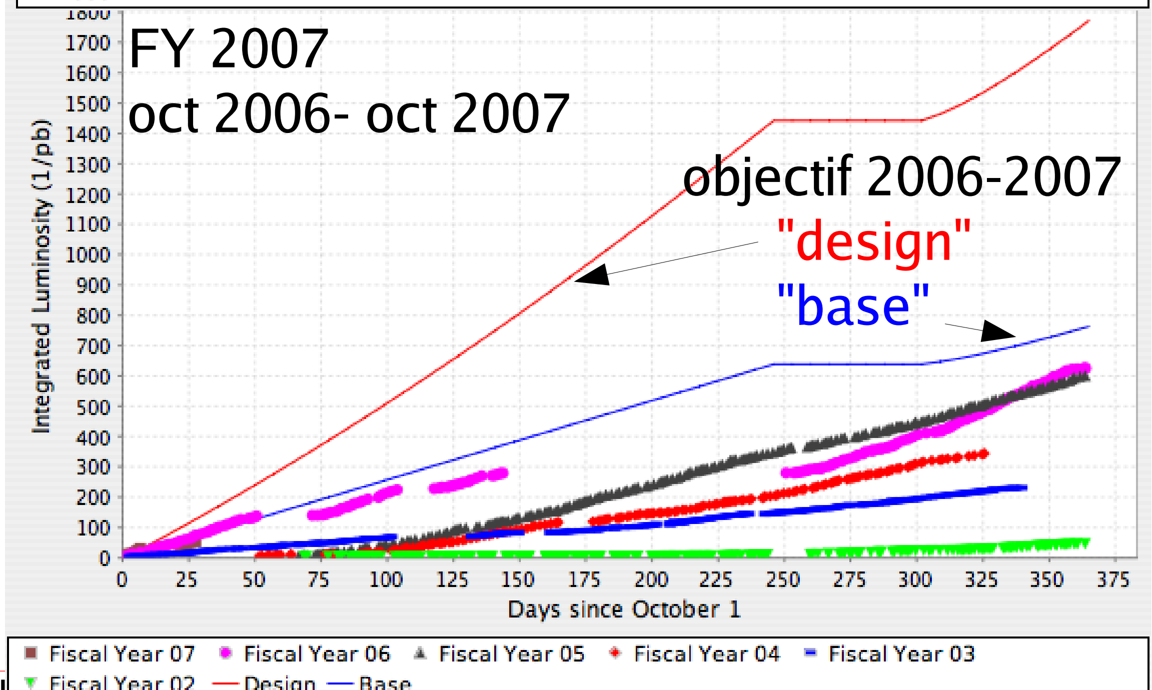


2006-2007

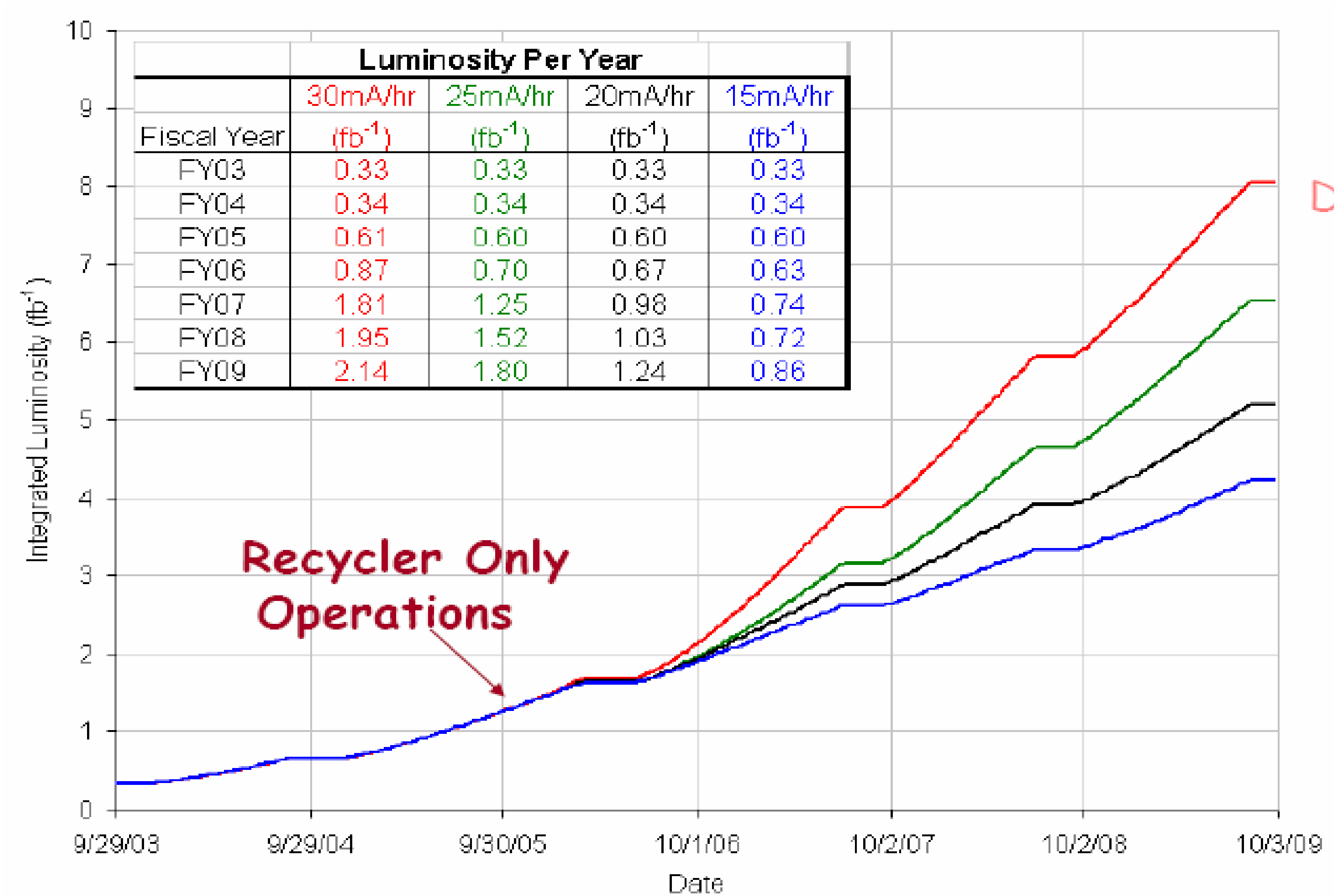
année charnière

« design » 1800 pb^{-1}

« base » 800 pb^{-1}

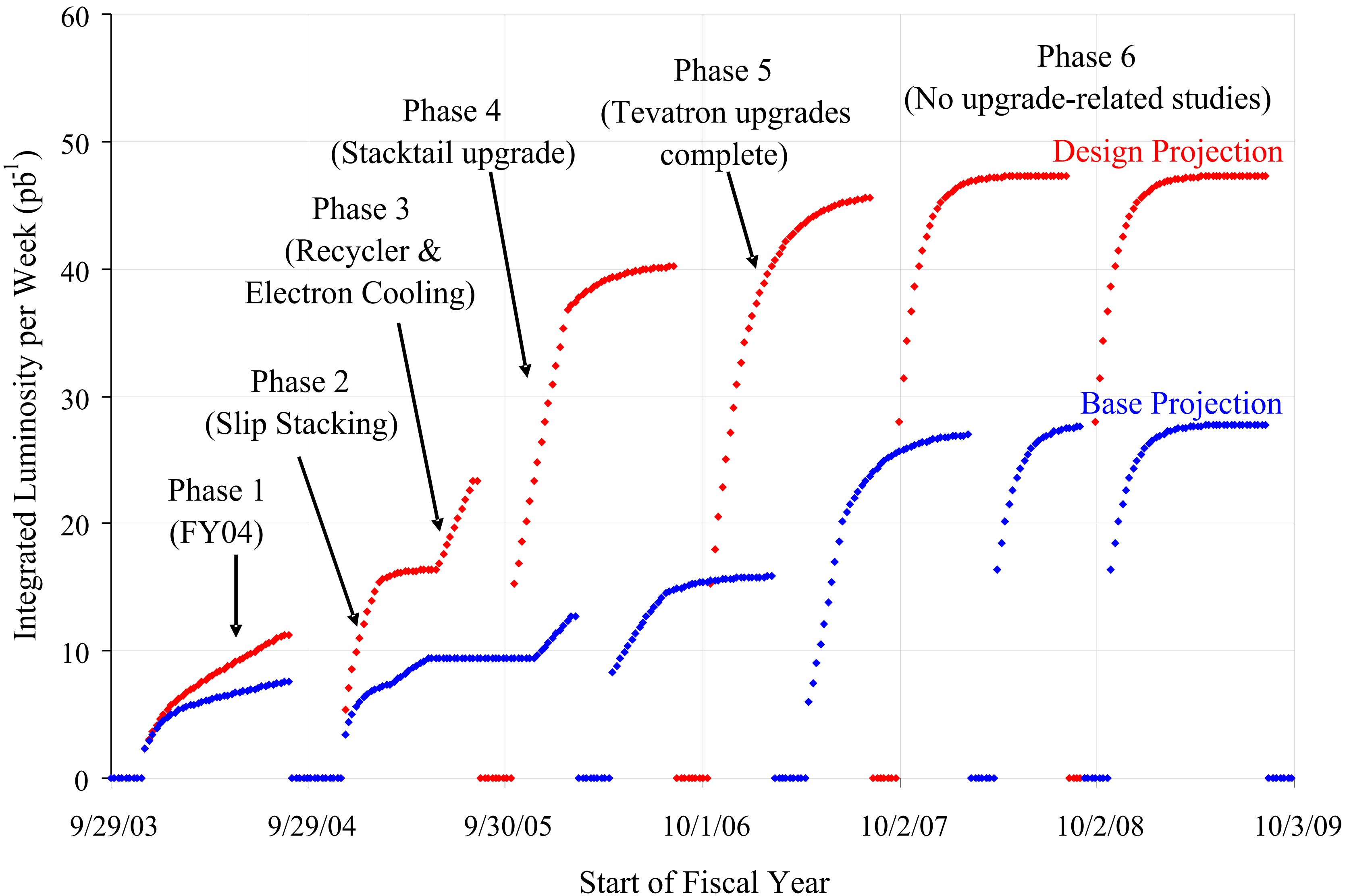


Tevatron Luminosité prospect en 2004



Luminosity Per Year				
Fiscal Year	30mA/hr (fb^{-1})	25mA/hr (fb^{-1})	20mA/hr (fb^{-1})	15mA/hr (fb^{-1})
FY03	0.33	0.33	0.33	0.33
FY04	0.34	0.34	0.34	0.34
FY05	0.61	0.60	0.60	0.60
FY06	0.87	0.70	0.67	0.63
FY07	1.81	1.25	0.98	0.74
FY08	1.95	1.52	1.03	0.72
FY09	2.14	1.80	1.24	0.86

Tevatron luminosity upgrades (2003)

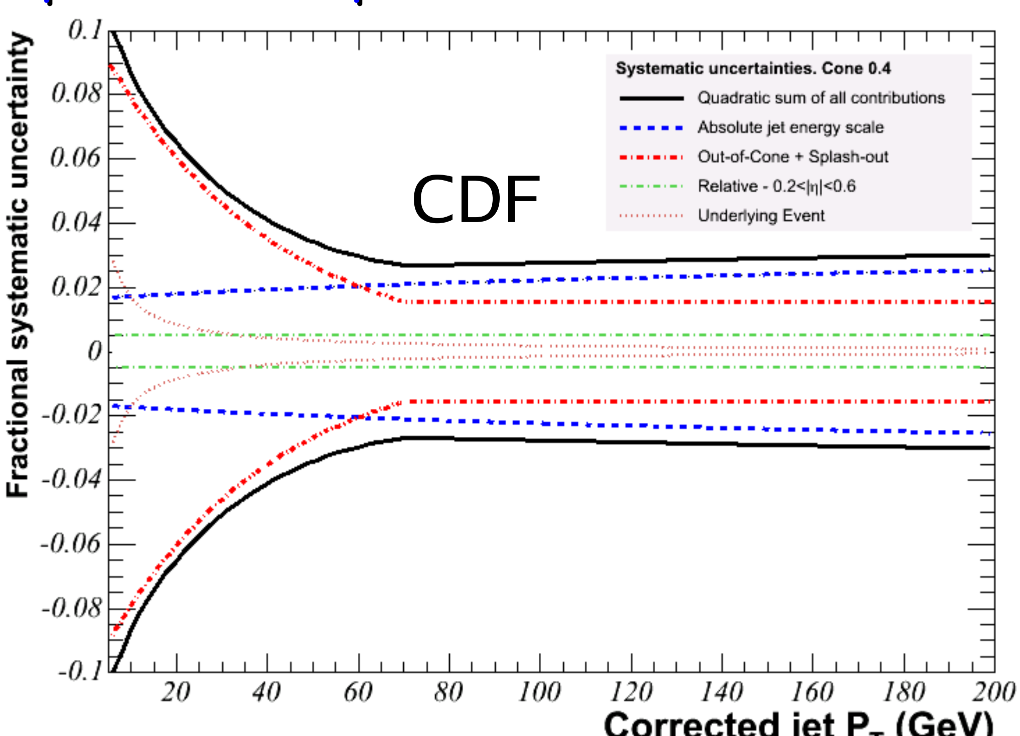


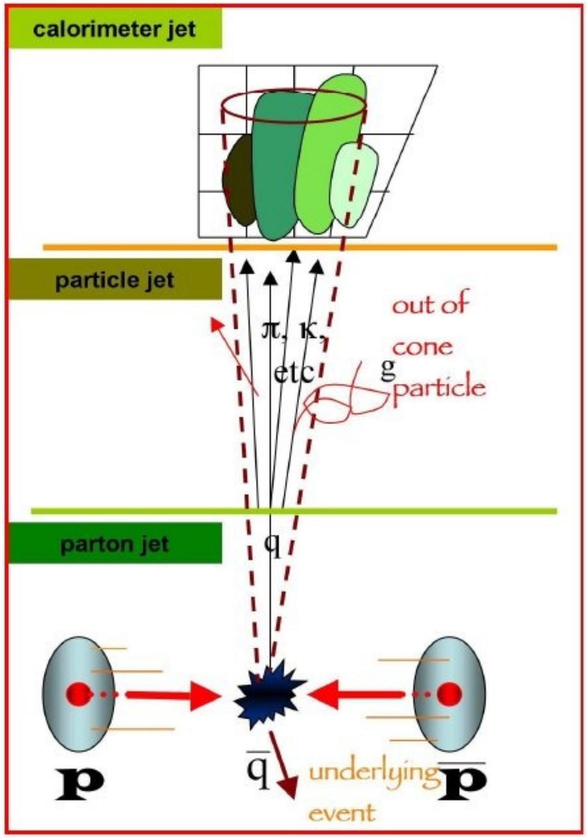
Jet Energy Scale

Energy measured in calorimeter is not parton energy:

- Limited cone size -> out of cone particles showering
- Different response for hadron/photon
- Uninstrumented regions
- Detector occupancy from
  - Noise
  - Pile-up from previous events
  - Extra interaction in same bunch crossing (typically ~2)

Calibrated using: γ+jet events, Z+jet events, single particles response, MC..





JES systematics, typically ~2-4%

Mécanisme de Higgs dans le MS

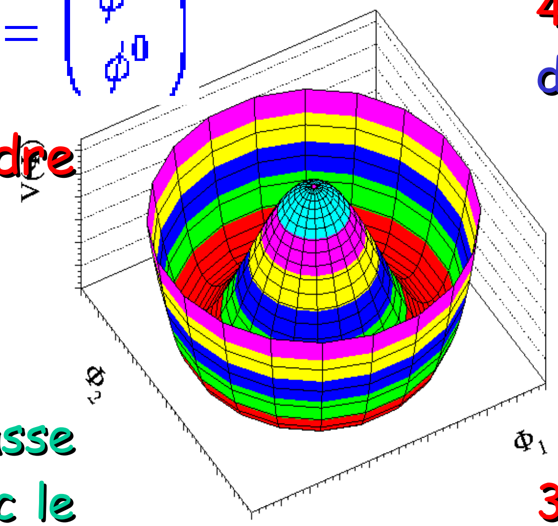
- Champ de Higgs =doublet sous SU(2)
- Potentiel associé invariant sous SU(2)xU(1)

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$$

4 degrés de liberté

$$V(\phi) = -\mu^2\phi^+\phi + \lambda(\phi^+\phi)^2$$

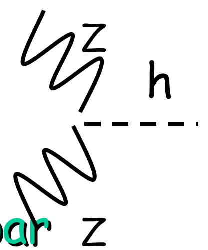
Brisure spontanée de la symétrie pour atteindre un minimum du potentiel



  - $\langle\phi\rangle = v/\sqrt{2}$ valeur dans le vide du champ
  - v=246 GeV

3 degrés de liberté

- Les bosons de jauge acquièrent une masse (polarisation longitudinale) via l'interaction avec le vide :
  - $m_W, m_Z \approx gv$

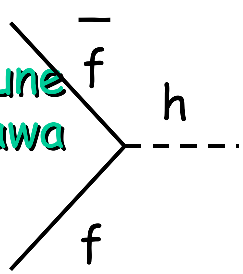


~gm_Z

- La masse du boson de Higgs est donnée par l'autocouplage λ :
  - $m_h = 2\sqrt{\lambda}v$ c 'est le paramètre inconnu

1 degré de liberté

- Le mécanisme de Higgs permet aussi de donner une masse aux fermions via les couplages de Yukawa (inconnus) :
  - $m_f \approx Y_f v$



$Y_f \sim g\, m_f/m_W$

Mécanisme de Higgs dans le MSSM

– Imposé par la supersymétrie

- 2 doublets de Higgs H_1, H_2
- H_1 se couple aux fermions down et H_2 aux fermions up
- Les couplages quartiques du potentiel sont les couplages de jauge (g,g')

– Conséquences

- 8 degrés de liberté 8= 5 + 3

5 bosons de Higgs
h, H (CP=1) ,A (CP=-1), H^+,H^-

3 masses pour
W^+, W^- et Z

- 2 valeurs dans le vide v_1 v_2 : $\tan\beta = v_2/v_1$
- Au premier ordre, 2 paramètres caractérisent le secteur ex : $\tan\beta$, m_h
- Les états CP=1 sont un mélange de H_1 et H_2 : angle de mélange α
- Les couplages aux bosons/fermions dépendent des angles : α et β

– ex : couplage hZZ~ $\sin(\beta-\alpha)$ couplage hAZ ~$\sin(\beta-\alpha)$ =1

- Relations entre la masse des Higgs et la masse des bosons de jauge

– au 1er ordre $m_h < m_Z|\cos 2\beta| < m_H \quad m^2_{H^\pm} = m^2_A + m^2_W$

Low Mass Higgs Search at DØ

- $W(\rightarrow e/\mu+\nu)H(\rightarrow bb)$: $\sigma x BR = 0.015$ pb
- $Z(\rightarrow ee/\mu\mu)H(\rightarrow bb)$: $\sigma x BR = 0.003$ pb
- $Z(\rightarrow \nu\nu)H(\rightarrow bb)$: $\sigma x BR = 0.015$ pb

for 261-389 pb^{-1}	eff	S	B	S/sqrt(B)
$W(\rightarrow e\nu)H$	3.4%	0.18	4.7	0.08
$W(\rightarrow \mu\nu)H$	1.7%	0.10	4.0	0.05
$Z(\rightarrow ee)H$	4.5%	0.05	1.4	0.04
$Z(\rightarrow \mu\mu)H$	5.9%	0.05	3.1	0.03
$Z(\rightarrow \nu\nu)H$	5.2%	0.21	9.0	0.07
$W(\rightarrow \nu)H$ miss lep.	4.2%	0.15	9.0	0.05