Tevatron SM Higgs Combined Result
~ Low Mass Region ~

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On behalf of CDF and DZero collaborations
Moriond EW, La Thuile Italy
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Method for Combination

At Tevatron: **High background (BG) and sizable systematic uncertainties**
→ Test **BG(b)** only and **BG+signal (s+b)** hypotheses
using **Poisson statistics accounting for systematic uncertainties.**

- We use two methods
  - Bayesian method (CDF) : Bayesian integration over likelihoods

$$\mathcal{L}(R,\vec{s},\vec{b}|\vec{n},\vec{\theta})\times\pi(\vec{\theta})=\prod_{i=1}^{N_C}\prod_{j=1}^{Nbins}\mu_{ij}^{n_{ij}}e^{-\mu_{ij}}/n_{ij}!\times\prod_{k=1}^{n_{np}}e^{-\theta_k^2/2}$$

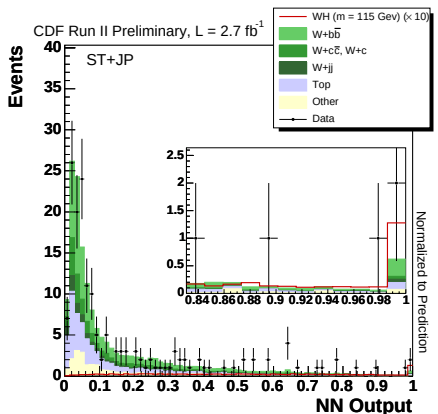
  - Modified Frequentist method, CLs (DØ)

$$LLR=-2\ln\frac{p(\text{data}|H_1)}{p(\text{data}|H_0)};\quad CL_b=p(LLR\geq LLR_{obs}|H_0)\quad CL_{s+b}=p(LLR\geq LLR_{obs}|H_1)\quad CL_s=\frac{CL_{s+b}}{CL_b}$$

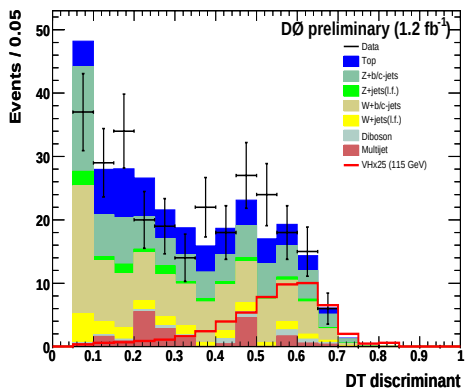
- Both methods use differential distributions, not only integrated yields.

There are 23 inputs from CDF and 52 inputs from DØ, they are orthogonal inputs.

CDF WH→lνbb



DØ VH→ννbb



Method for Combination, cont.

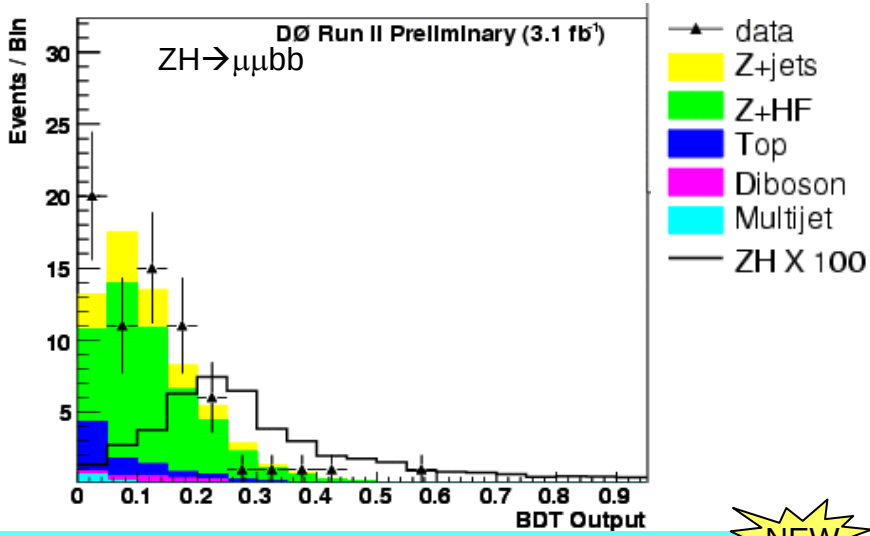
- Treatment of systematic uncertainties
  - Systematics are included via Gaussian smearing of expected number of events.
  - Correlations of systematic uncertainties are included across all input channels.
  - CLs method fits uncertainty parameter values for each hypothesis
  - Bayesian method integrates over uncertainty parameters.

- Correlated uncertainties between CDF and DZero analyses
  - Luminosity (4%),
  - Cross section: Higgs(6%,12%), top(10%), single top(10%), diboson(6%).
- Correlated uncertainties in CDF
  - b-tagging(5-12%), JES(3-10%), gluon radiation (3-4%).
- Correlated uncertainties in Dzero
  - b-tagging(4-15%), JES(3-5%), JetID/resolution(3-5%)

Updated Inputs

Approved yesterday DØ combination only

- DØ ZH→llbb (3.6 fb^{-1})
  - 2lepton+2bjets
  - Improvements
    - Electron: includes gap region
    - Muon: add μ + track events.
    - Improve dijet mass resolution using kinematic fitting.
  - b-ID: 2 loose and 1 tight
  - MVA: BDT



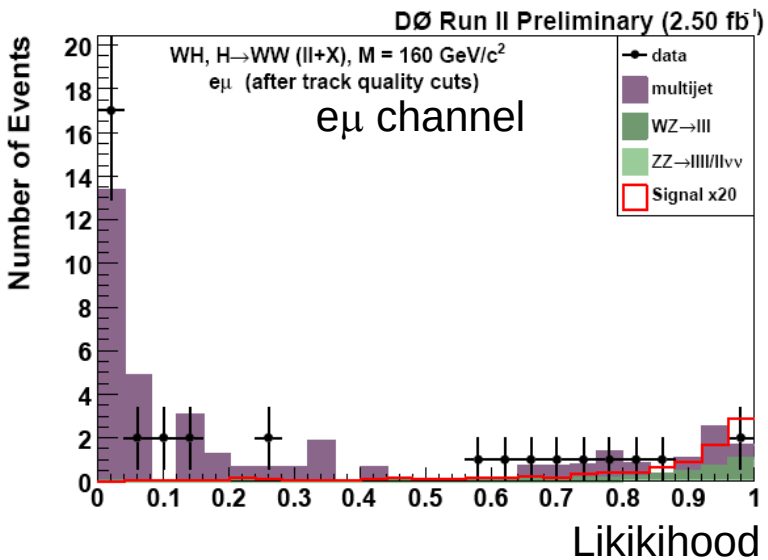
NEW

Limit / SM @ m_H=115GeV
DØ 3.6 fb^{-1}: **exp (obs) 8.0(9.1)**

- DØ WH→WWW*→$l^{\pm}\nu l^{\pm}\nu$+X (3.6 fb^{-1})
  - Signal: Like sign di-lepton (ee, eμ, μμ)
  - BG: charge flip
    multi-jet
- MVA: multi-dim likelihood

NEW

Result: Limit / SM @ m_H=160GeV
DØ : 3.6 fb^{-1}: exp (obs) 11 (18)



Inputs for Combined Result

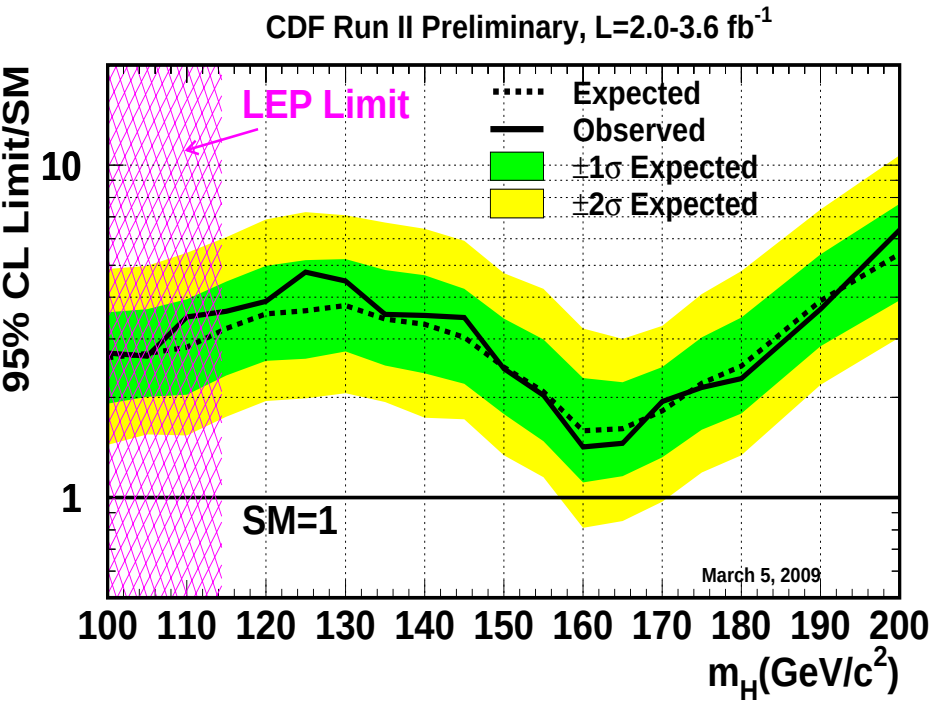
- In total, 23 inputs from CDF, 52 inputs from DØ

Limits are at m_H=115GeV

Production	Decay	CDF		DØ	
		Lumi	Limit/SM exp (obs)	Lumi	Limit/SM exp (obs)
WH	$l\nu$ bb	2.7	4.8 (5.6)	2.7	6.4 (6.7)
WH	$\tau\nu$ bb	----	-----	1.0	42 (34)
ZH	ll bb	2.7	9.9 (7.1)	3.6	8.0 (9.1) *
VH	$\nu\nu$ bb	2.1	5.6 (6.9)	2.1	8.4 (7.5)
VH	jjbb	2.0	37 (38)	-----	-----
All	τ + jets	2.0	30 (24)	1.0	42 (44)
All	$\gamma\gamma$	-----	-----	4.2	18 (13)
ttH	ttbb	-----	-----	2.1	45 (64)

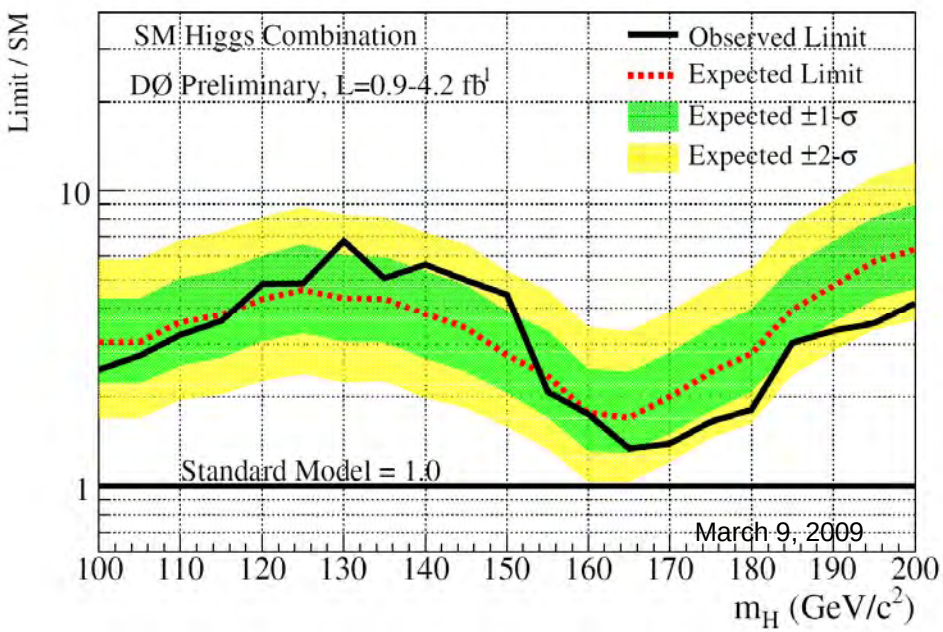
CDF and DØ Individual Combinations

CDF Combination (2009 Mar)



Limit / SM @ m_H = 115 GeV
CDF : exp 3.2 obs 3.8

DØ Combination (2009 Mar)

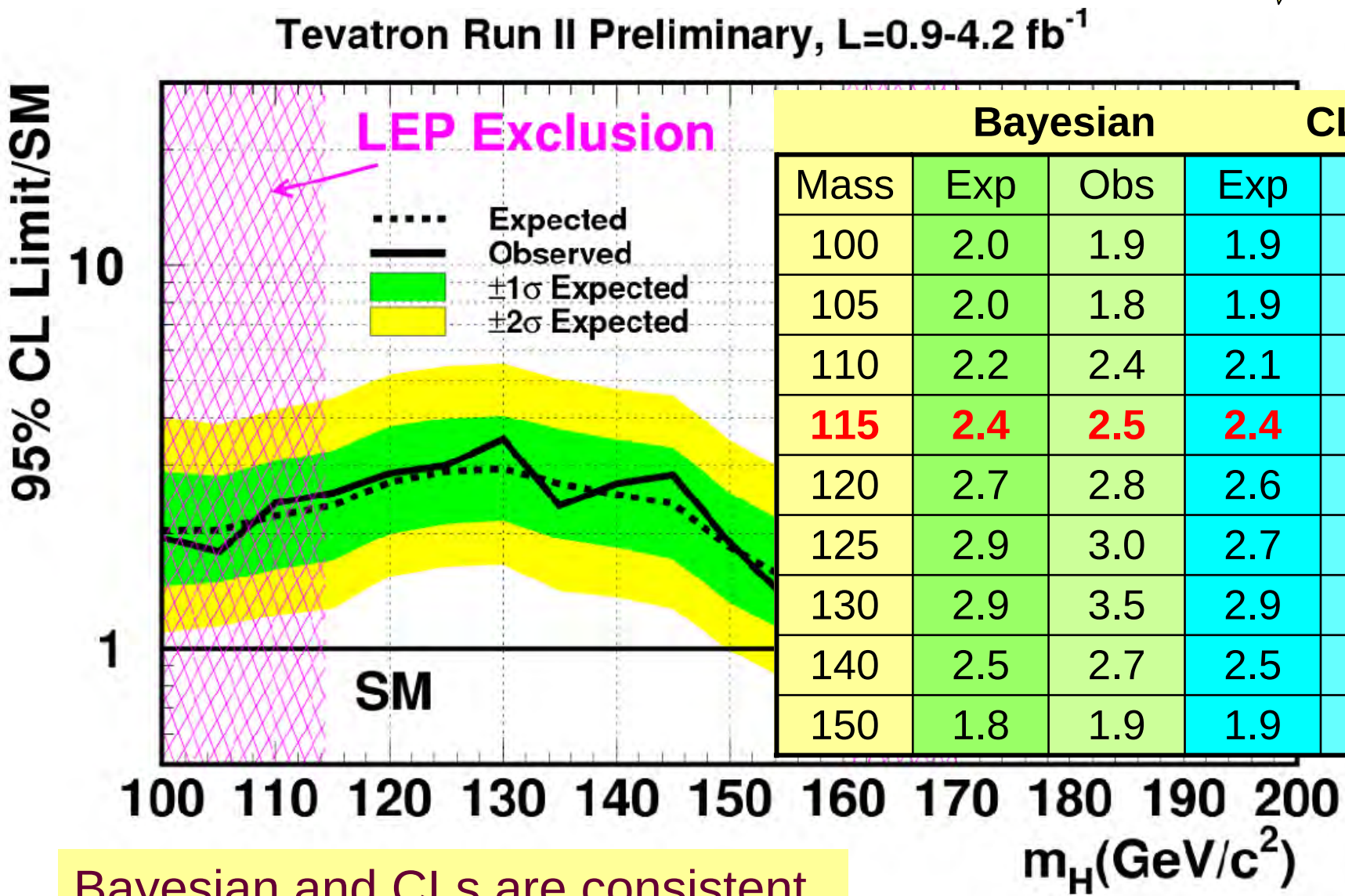


Limit / SM @ m_H = 115 GeV
DØ : exp 3.8 obs 3.6

NEW

Combined Limit for Low Mass Region

NEW

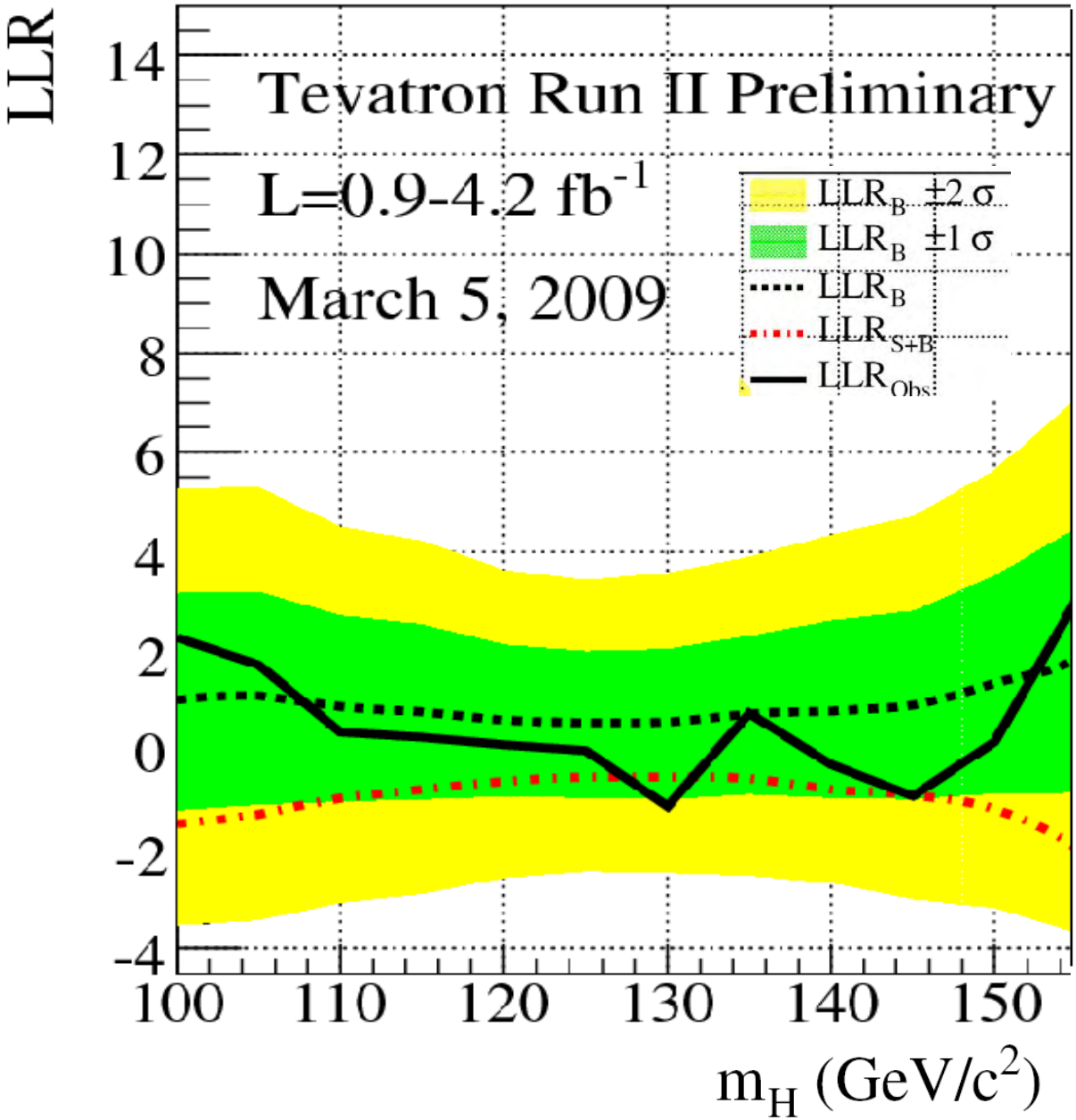


	Bayesian		CLs	
Mass	Exp	Obs	Exp	Obs
100	2.0	1.9	1.9	1.7
105	2.0	1.8	1.9	1.7
110	2.2	2.4	2.1	2.2
115	**2.4**	**2.5**	**2.4**	**2.6**
120	2.7	2.8	2.6	2.8
125	2.9	3.0	2.7	2.9
130	2.9	3.5	2.9	4.0
140	2.5	2.7	2.5	3.1
150	1.8	1.9	1.9	2.0

Bayesian and CLs are consistent.
No excess is observed.

Log Likelihood Ratio for Tevatron Combination

NEW



Plot shows if data looks Background like or Signal+Background like.

↑ **Background like**

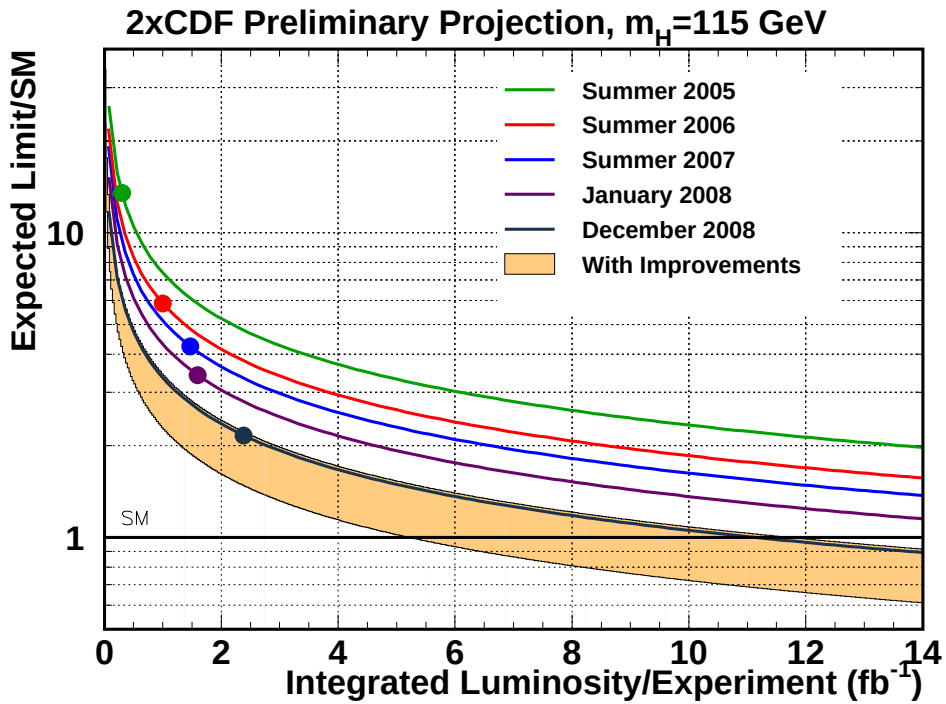
↓ **Signal like**

Summary at low mass

- Tevatron combination for Moriond09 is released.
  Thanks to accerelerator division and both CDF and DØ collaborations.
- Result: no excess is observed at low mass.

Exp/SM: 2.4 Obs/SM: 2.5 @ m_H = 115GeV

m_H<150 GeV: expected limit always below 3xSM!
→ Analyses are based on average ~ 2.5 fb^{-1}.

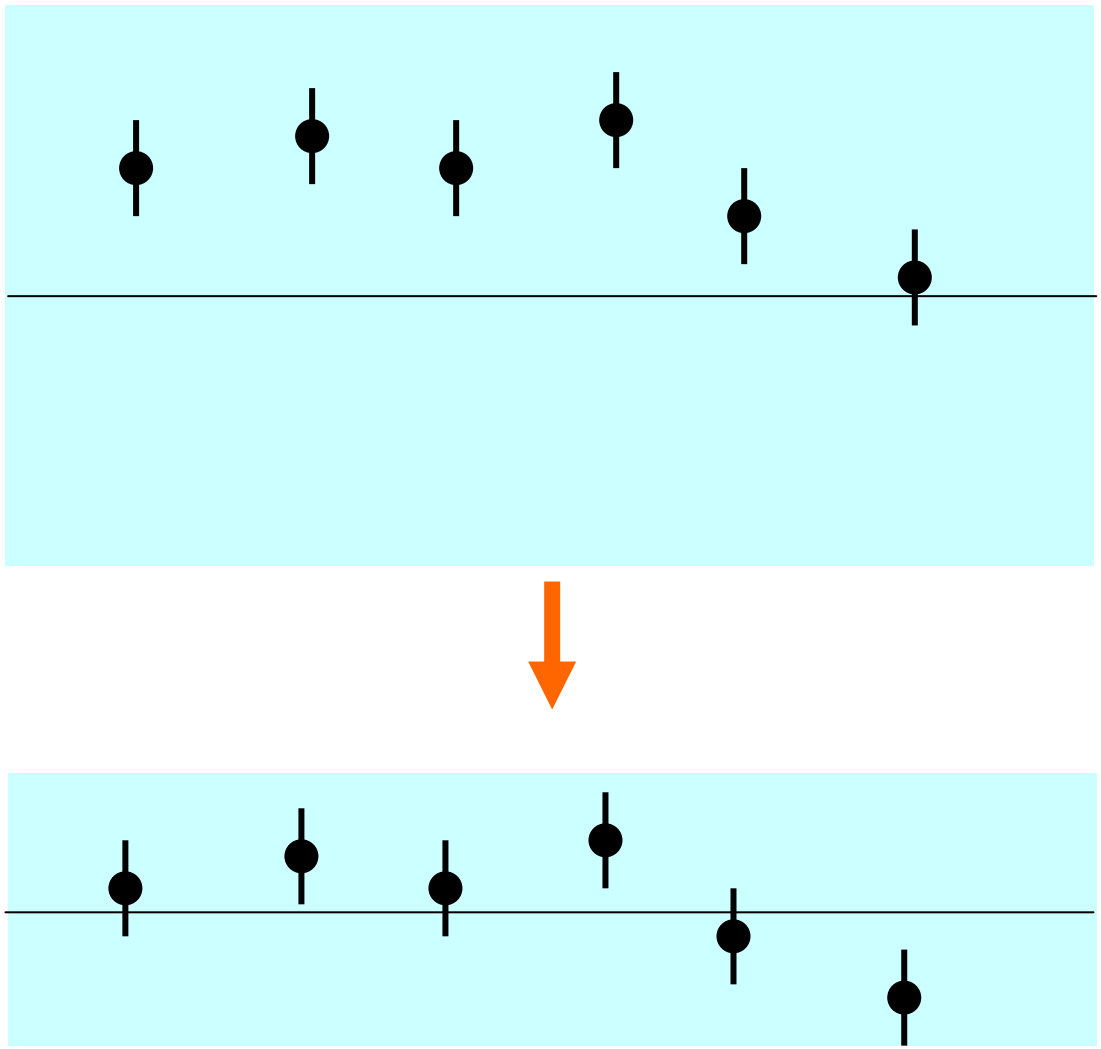


Result improves almost linearly with $\int \mathcal{L}\, dt$, *not* $\sqrt{\int \mathcal{L}\, dt}$.

Both experiments will present results with more than 5 fb^{-1} this Summer!

backup

Constraining Systematic uncertainties with Data



Background prediction
+ uncertainty

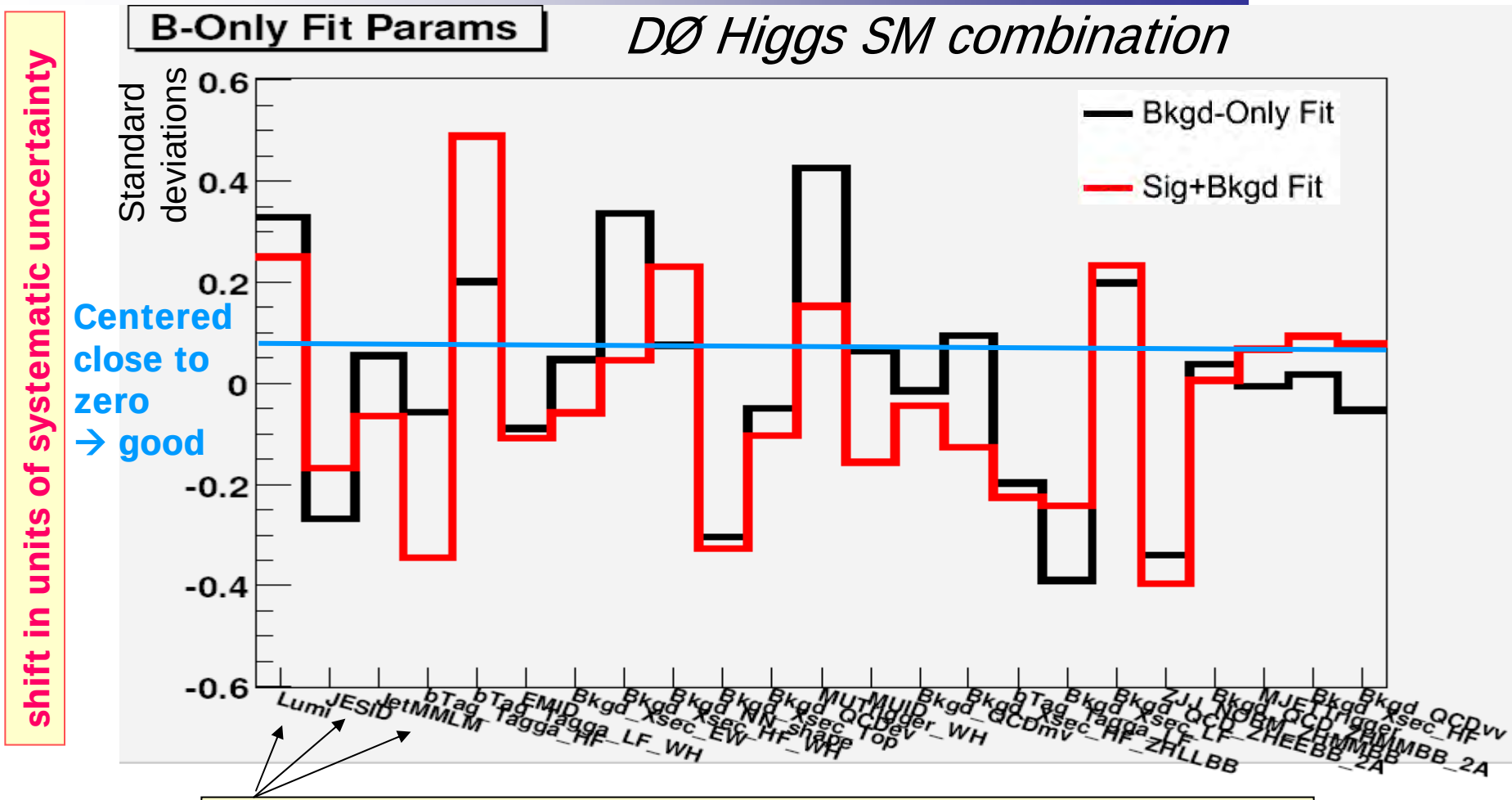
AKA side band fitting

uncertain parameters introduced in the χ^2 of the fit allow shifting of central value of the background estimation

Systematic uncertainty width gets also constrained

Shape of the systematic is also taken into account

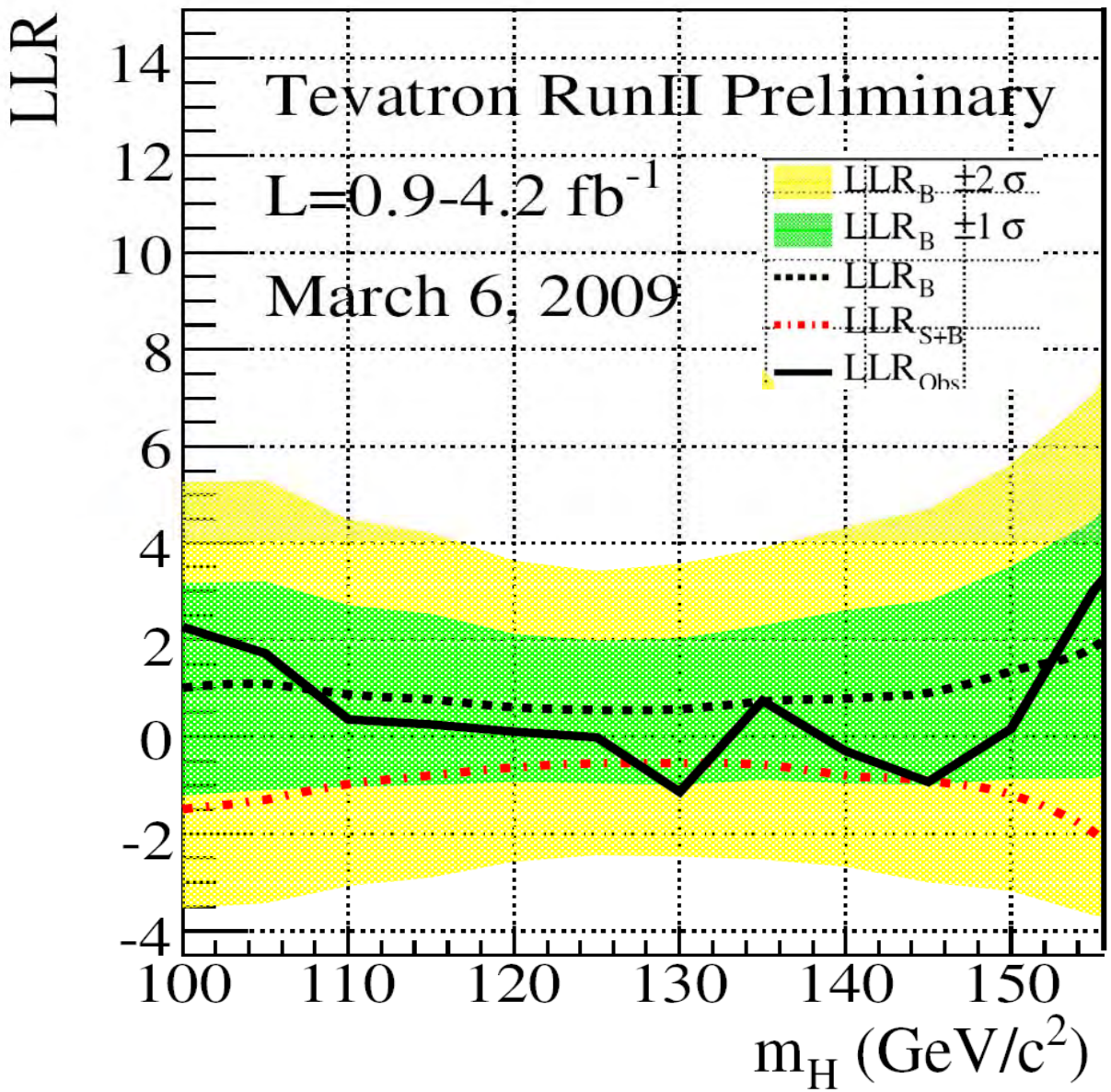
Best fit for nuisance parameters

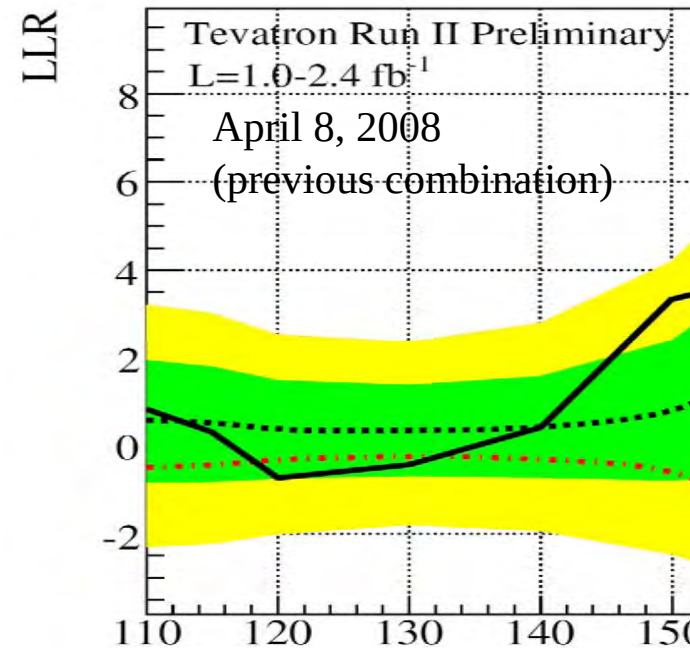


Input: Data,

Signal, BG (Wbb, Wjj, top, singletop, diboson, multi-jet)

Log Likelihood Ratio for CDF DZero combination





↑ **Background like**

↓ **Signal like**

Combined CDF/D0 High Mass Higgs Boson exclusion limits at the Tevatron

Doug Benjamin

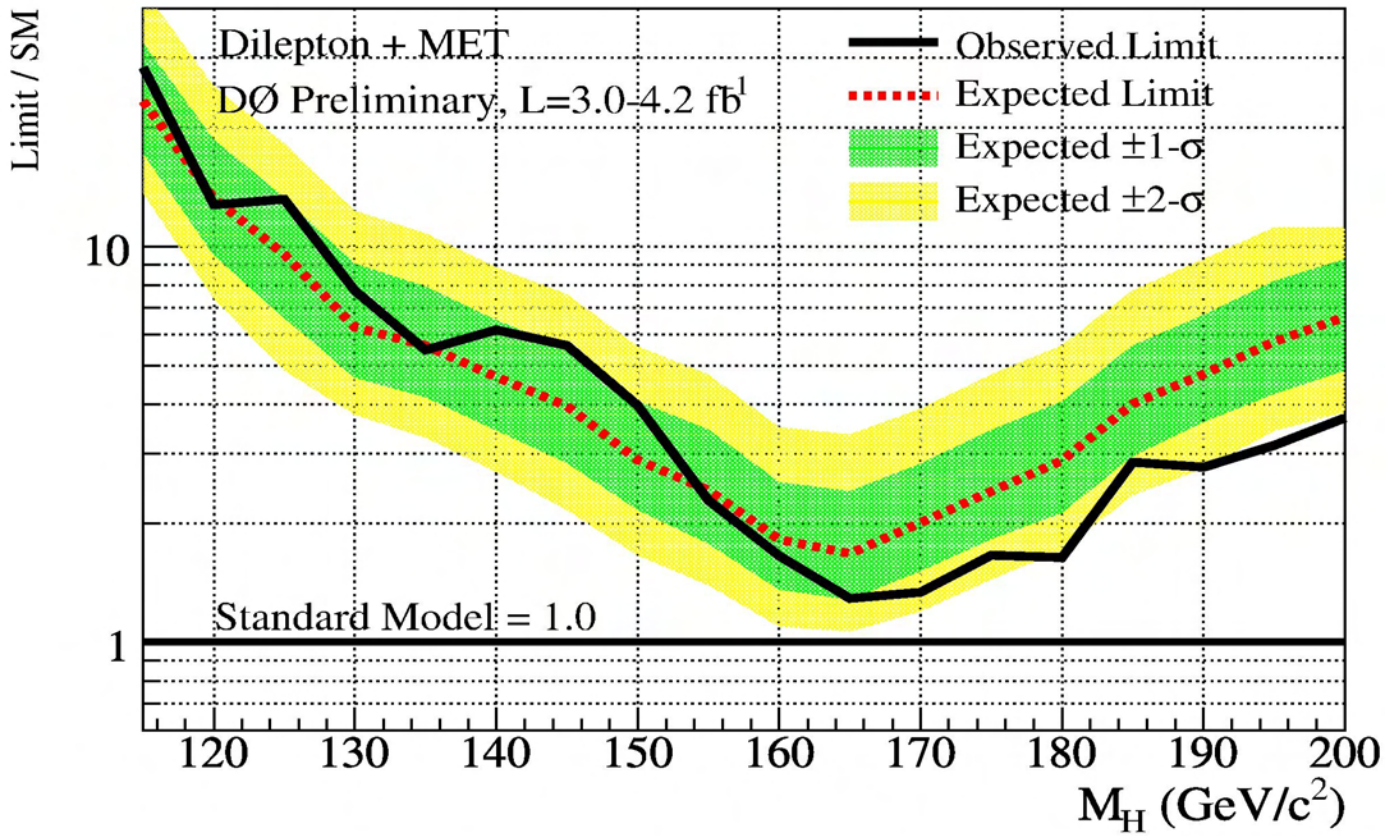
Duke University

On behalf of the CDF and D0 Collaborations

Moriond EWK, La Thuile, Italy

March 8-14, 2009

H → WW* → l ν l ν Limits



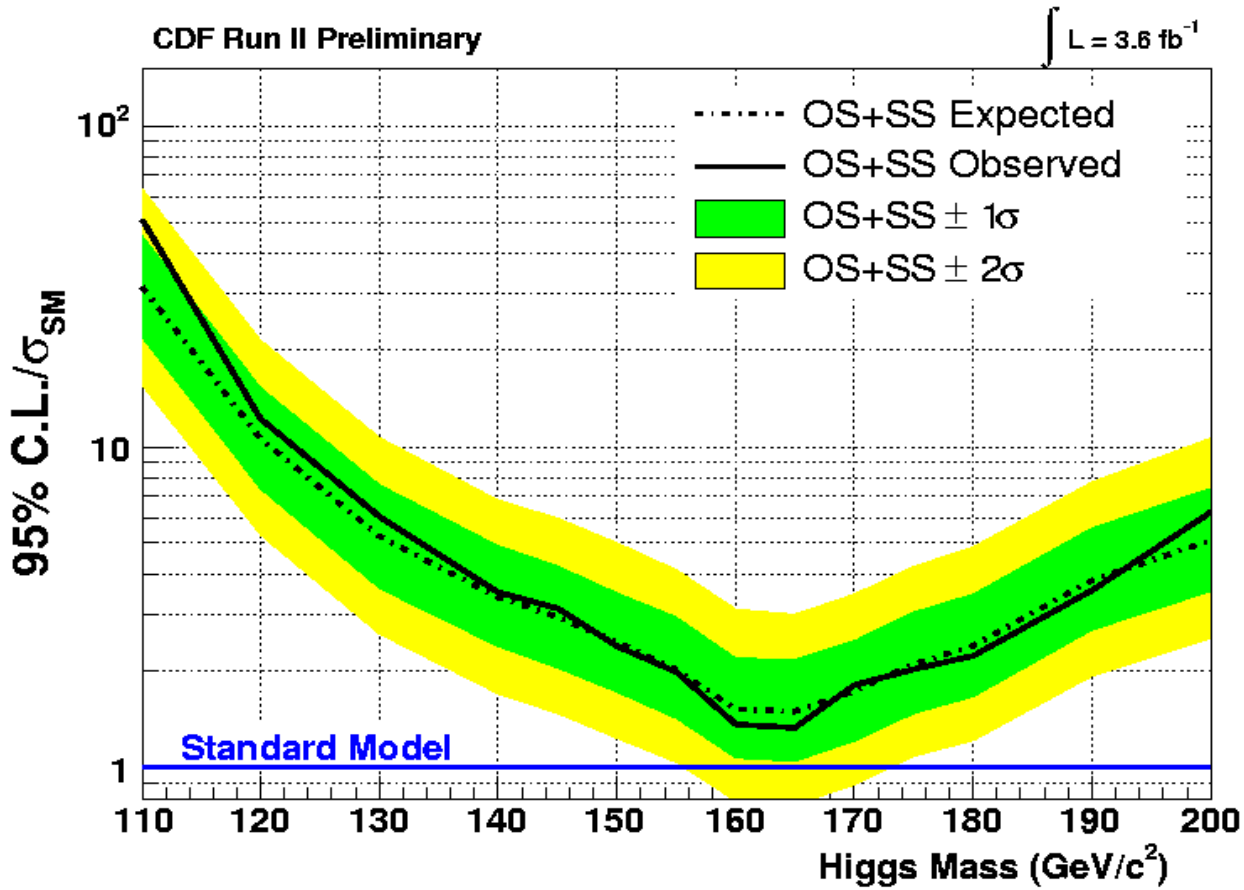
For M_H = 165

Exp limit 1.7 x σ_{SM}

Obs limit 1.3 x σ_{SM}

Use latest theoretical inputs including:
σ(gg→H) by C. Anastasiou, R. Boughezal & F. Petriello;
and de Florian & Grazzini w/ MSTW 2008 NNLO PDF set

CDF H → WW* Limits



Combined analyses (opposite sign dileptons and same sign dilepton analysis) into one result

At M_H = 165,

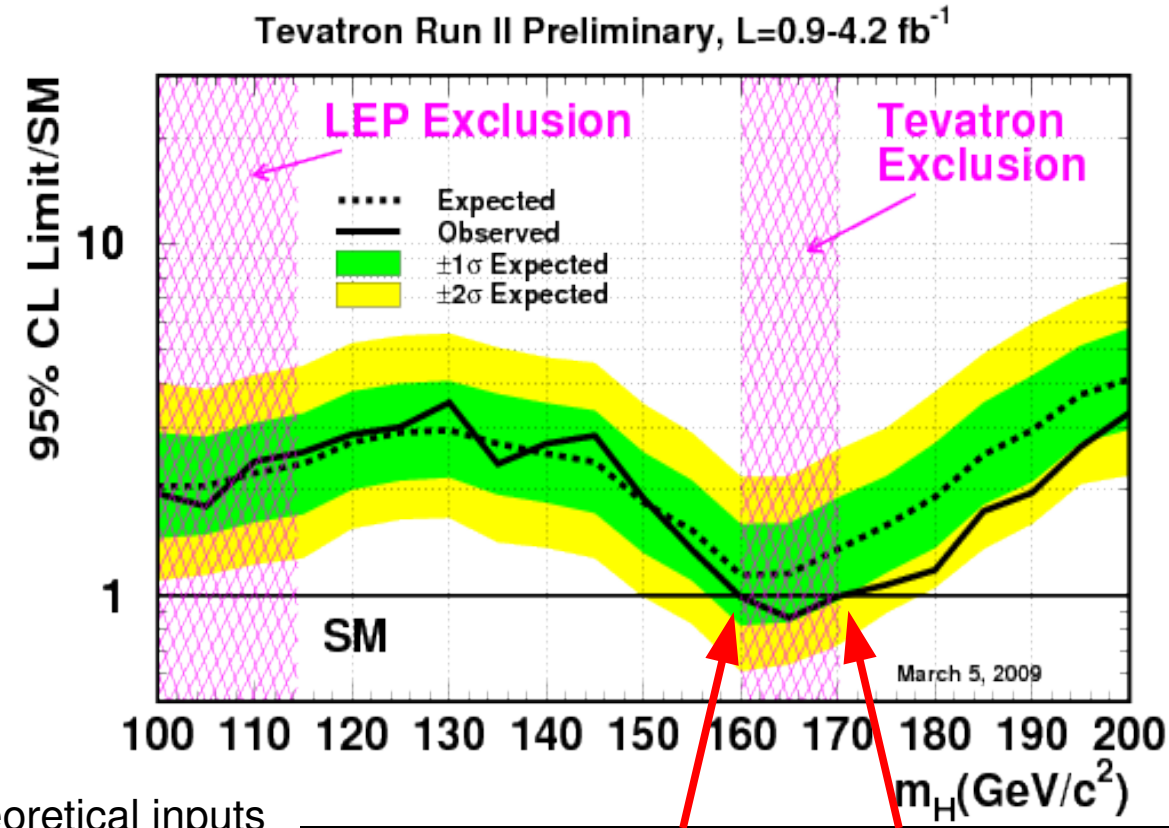
Exp limit - 1.5xσ_{SM}

Obs limit- 1.3xσ_{SM}

Use latest theoretical inputs including:

σ(gg→H) by C. Anastasiou, R. Boughezal & F. Petriello; and de Florian & Grazzini w/ MSTW 2008 NNLO PDF set

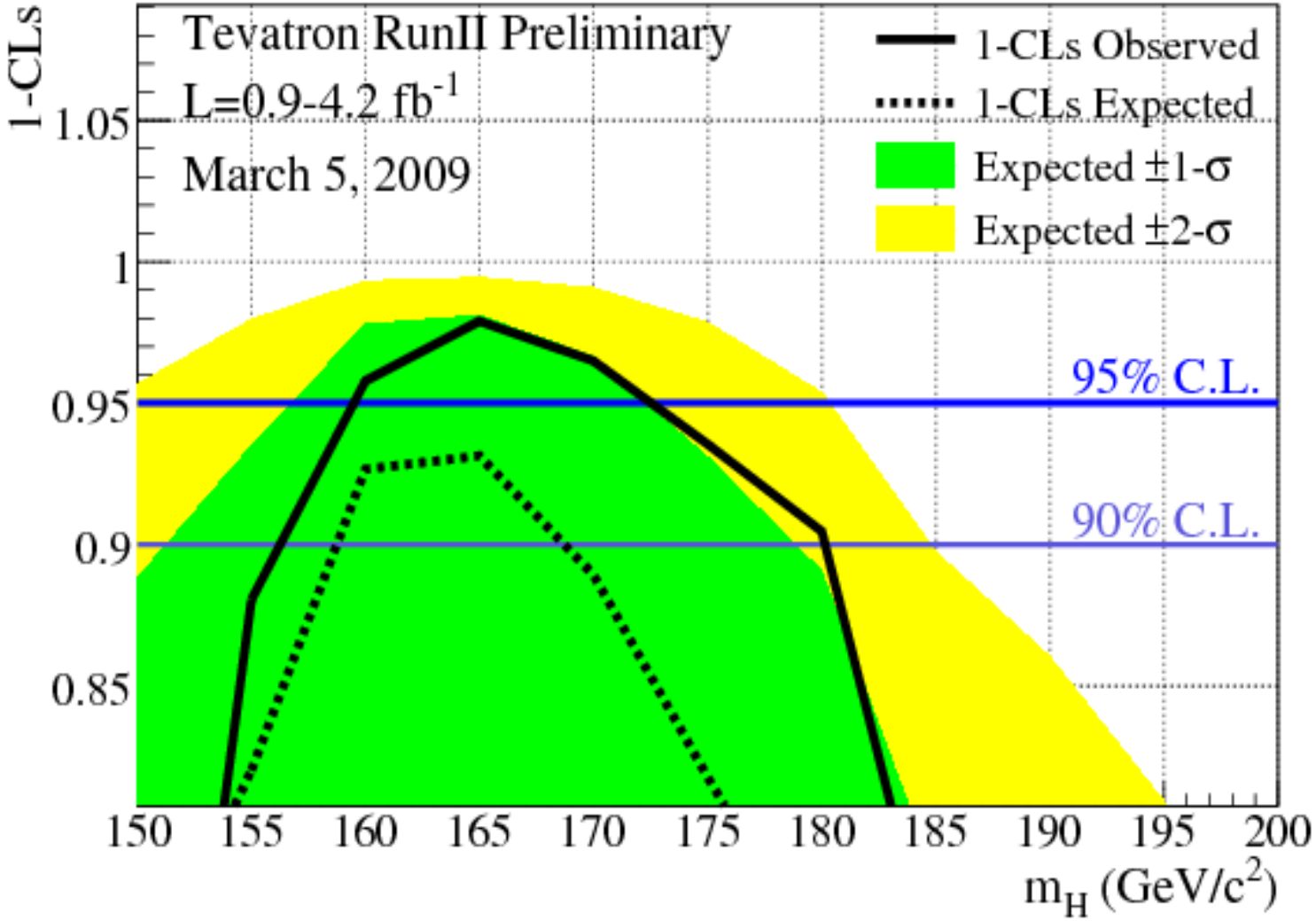
Tevatron Combination



Use latest theoretical inputs including:
σ(gg→H) by C. Anastasiou, R. Boughezal & F. Petriello; and de Florian & Grazzini w/ MSTW 2008 NNLO PDF set

Bayesian	155	160	165	170	175	180	185	190	195	200
Expected	1.5	1.1	1.1	1.4	1.6	1.9	2.2	2.7	3.5	4.2
Observed	1.4	0.99	0.86	0.99	1.1	1.2	1.7	2.0	2.6	3.3
Cls	155	160	165	170	175	180	185	190	195	200
Expected	1.5	1.1	1.1	1.3	1.6	1.8	2.5	3.0	3.5	3.9
Observed	1.3	0.95	0.81	0.92	1.1	1.3	1.9	2.0	2.8	3.3

Tevatron Combination



Summary

- Exciting times for high mass Higgs searches at the Tevatron!
- Using combined CDF and D0 results -
  - SM Higgs is excluded with the mass range

$$160 - 170\ \mathrm{GeV}/c^2\ @\ 95\%\ \mathrm{CL}$$

- Tevatron making great strides in high mass Higgs searches
  - The machine continues to work well
  - Sensitivity continues to improve faster than luminosity scaling
  - Rapid incorporation of new data and analysis improvements
- Papers are in progress for both experiments

Backup Slides

$H \rightarrow WW^* \rightarrow l \nu l \nu$ Systematics

Syst(%)	Signal	ΣBkgd
Jet recon	6-18 %	
Jet E scale	3- 17 %	
Jet E reso	2%	
P_T model	1-5%	
lepton recon	2.5-4 %	
lepton mom.	2-8%	
theoretical σ	10%	6-20%
multi jet bkgd	2-20%	
luminosity	6.1%	

Two classes of systematic:

Shape systematics

Modify output of discriminant

Also change normalization

Flat systematics

Affect only normalization, do not modify shape

$H \rightarrow WW^* \rightarrow l\,\nu\,l\,\nu$ Systematics

Syst(%)	Signal	ΣBkg
JES	8.7	1.1
Lepton Energy	3.1	0.0
Miss Et Model	1.0	2 - 5
Conversion	0	1 - 4
WW NLO	10	10
σ (PDF, scale)	12	10
Multijet	0	4
Lepton ID	1.9	1.9

Two classes of systematic:

Shape systematics

Modify output of discriminant

Studied but found to be negligible

Flat systematics

Affect only normalization, do not modify shape