Higgs Hunting Workshop Experimental Summary

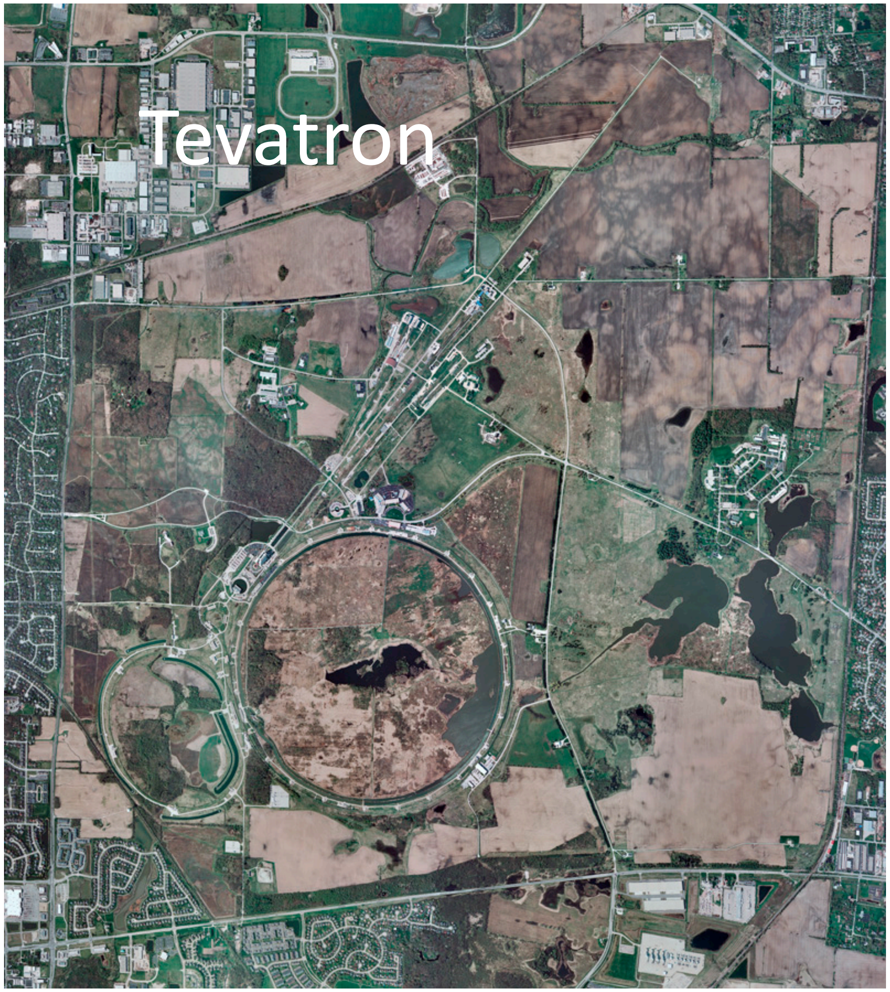
Tom Junk

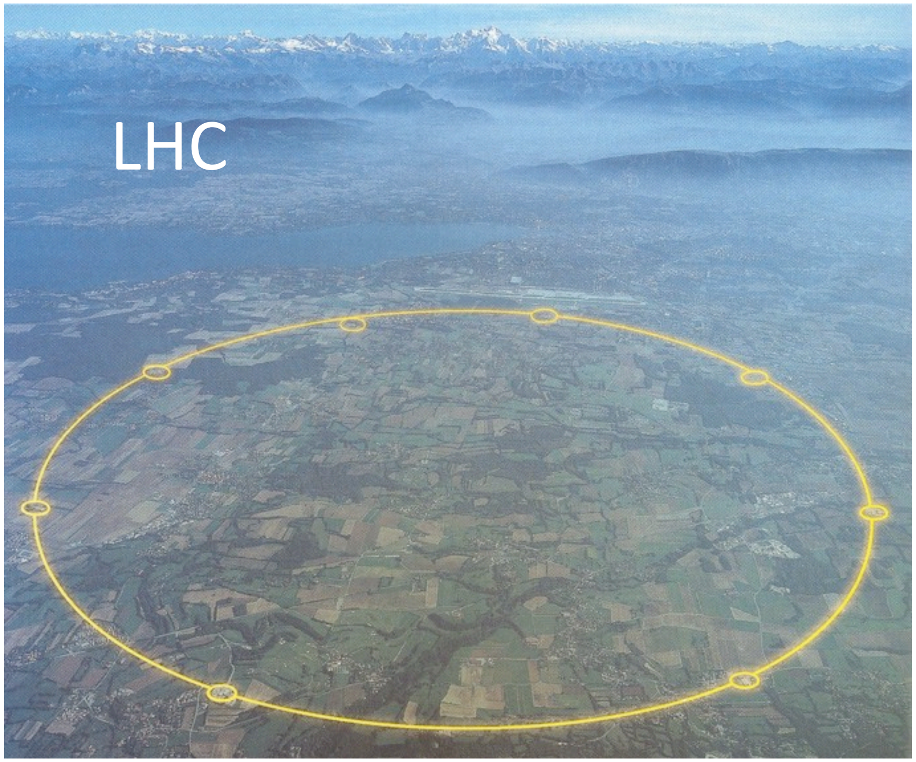
Fermilab

July 31, 2010

Orsay, France

The Accelerators





approx 27 Km around

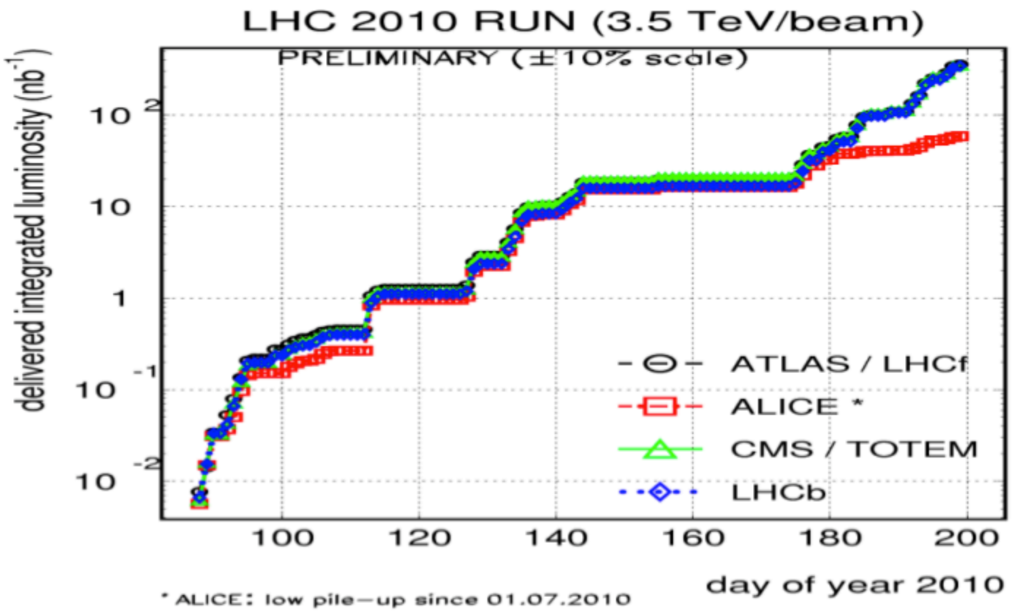
pp at 7+ TeV

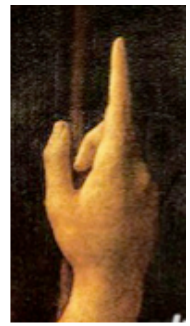
approx 4 miles around (6.3 Km)

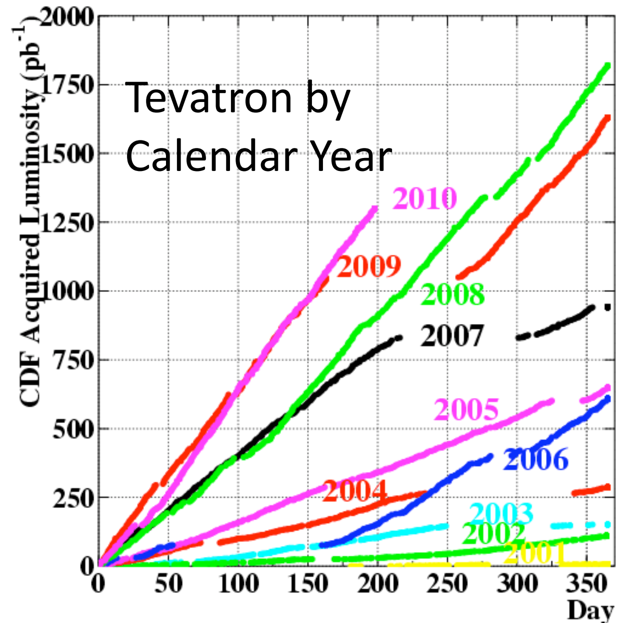
p-pbar at 1.96 TeV

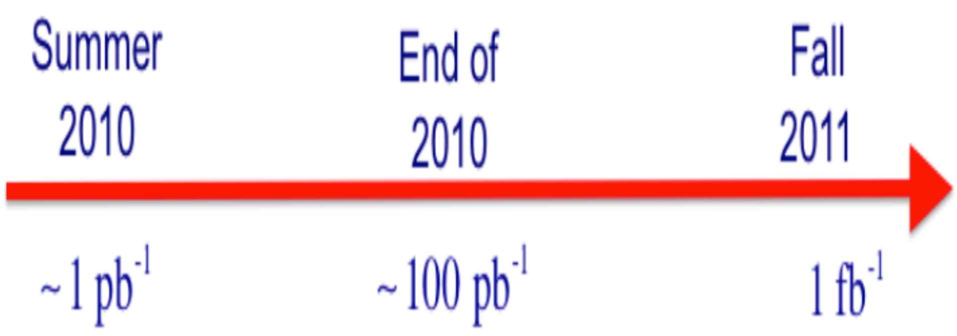
Superconducting Magnets!

Luminosities are Increasing





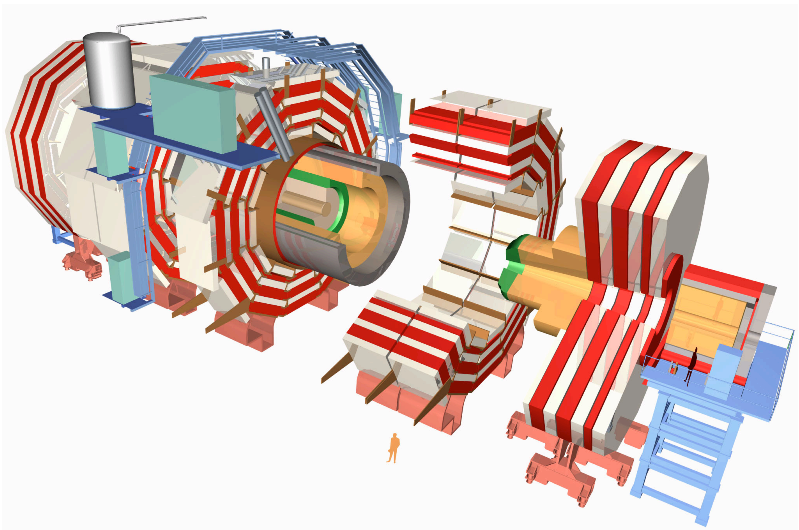


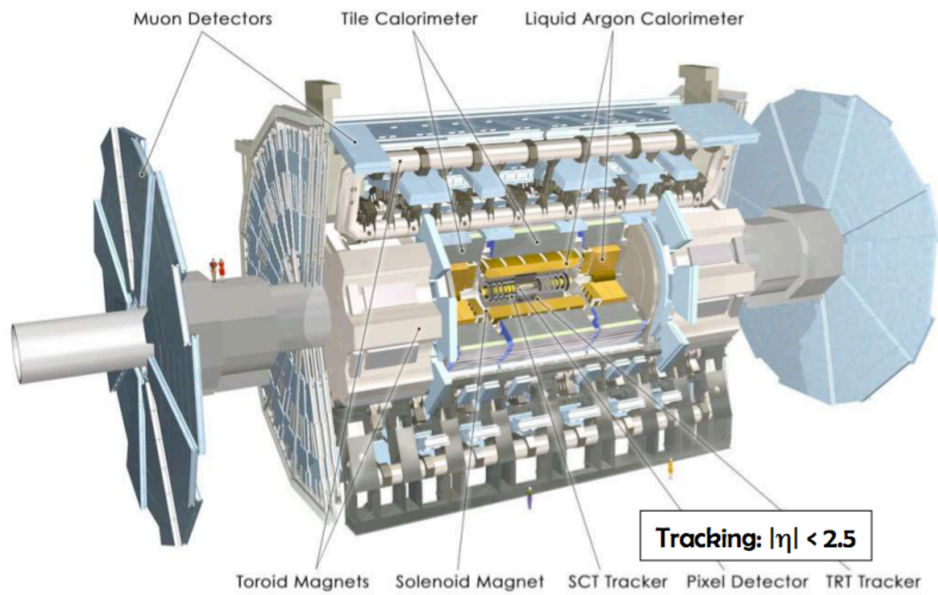


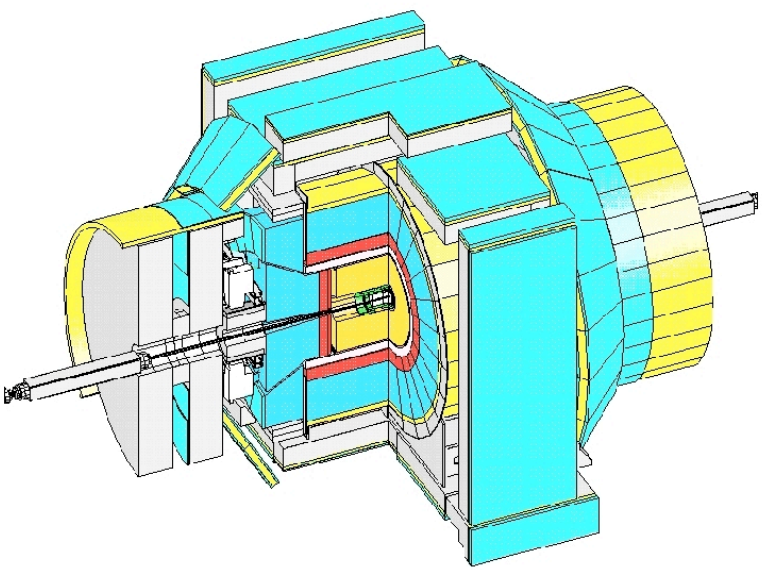
Fernandez

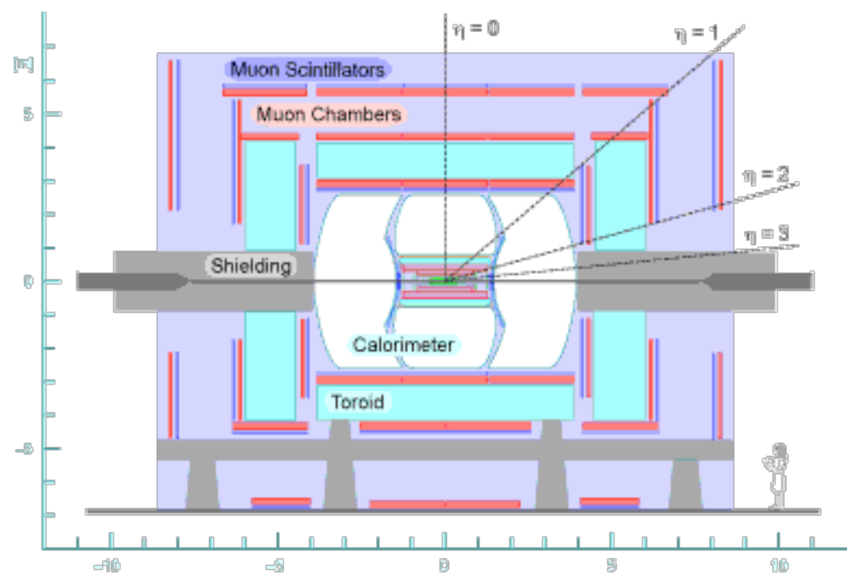
We owe a great debt to our colleagues in the Accelerator and Computing Divisions

The Detectors (Not to Scale)

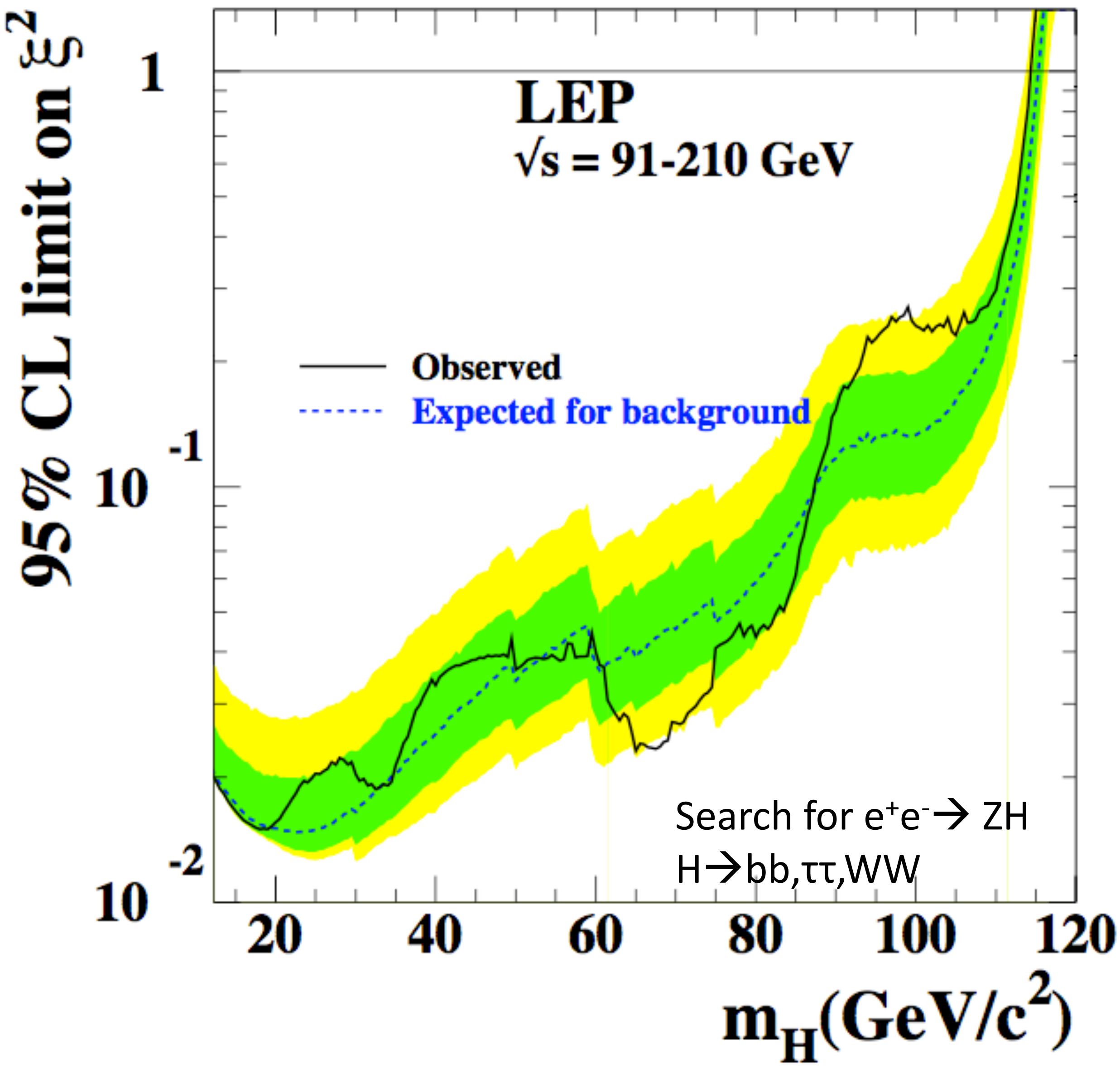






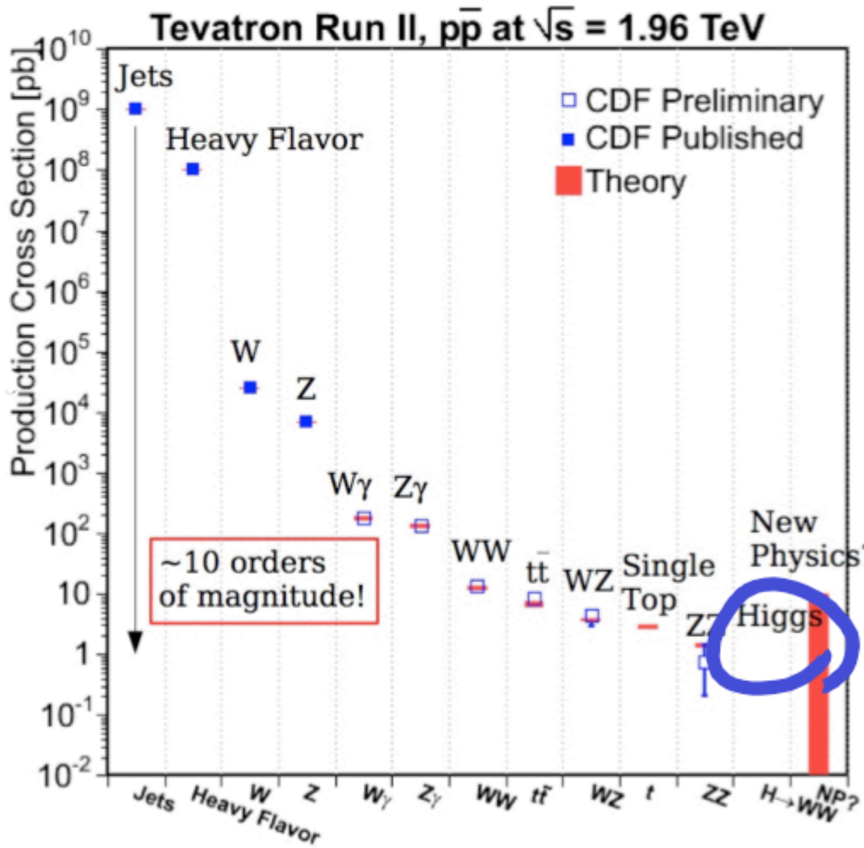


The Historical SM Higgs Context – LEP excludes SM $m_H < 114.4$ GeV

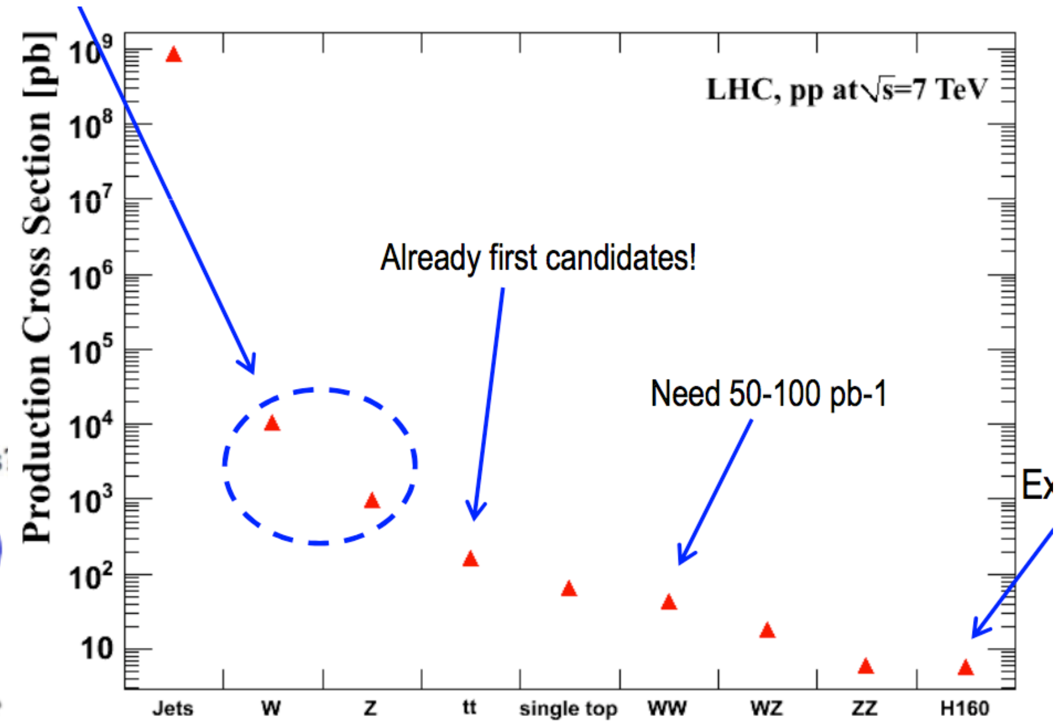


Small excesses seen at m_H=97 GeV and 115 GeV

The Scale of the Problem



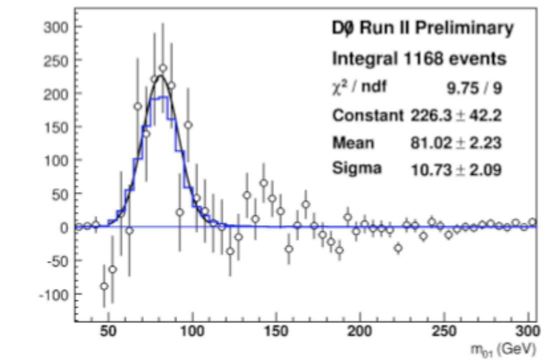
F. Margaroli

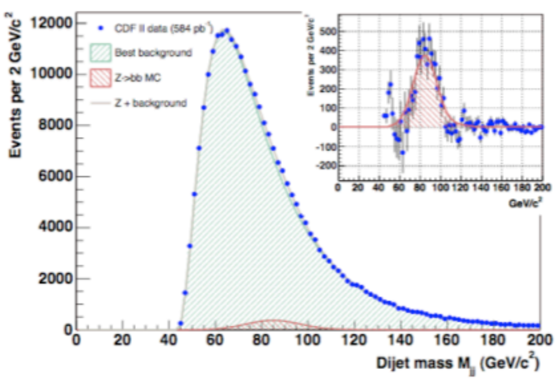


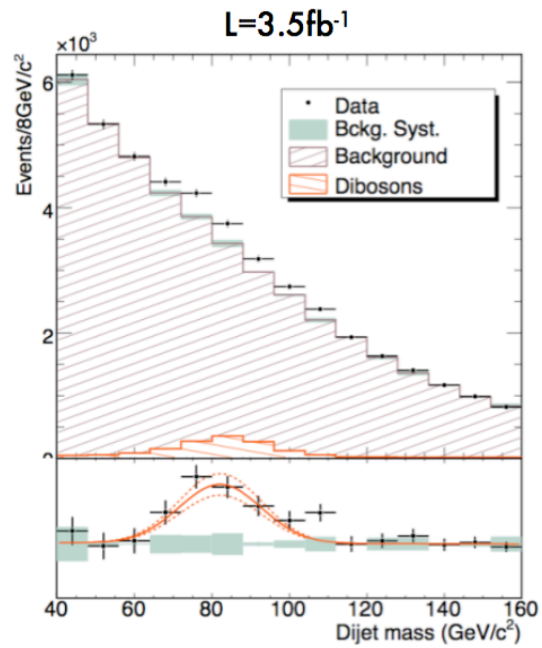
C. Ochando

Rapid progress through this plot expected.

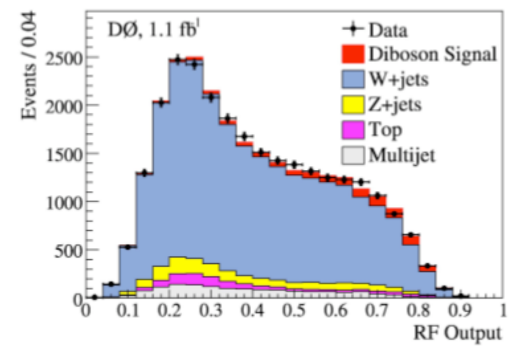
The Tevatron – Gaining Confidence in Searches with Standard Candles







F. Margaroli



$\sigma(WW+WZ)= 20.2 + 4.5$ pb

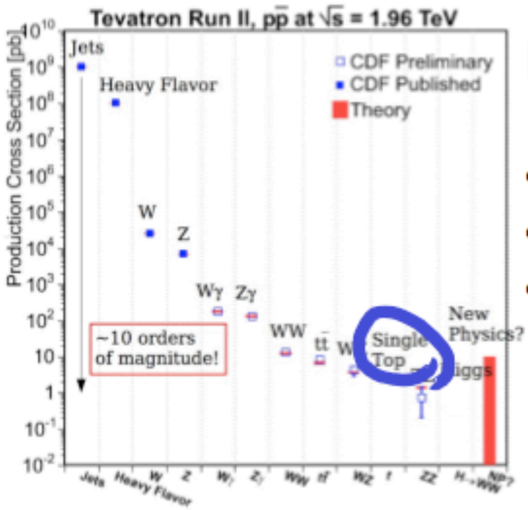
Z→b bbar
Calibrates/checks
b-jet energy scale
b-tag efficiency
Techniques for separating small signals from large backgrounds using sideband data to model backgrounds

WW+WZ Diboson observation in MET+Jets

Similar, but with a much smaller cross section

D0 Diboson with a Multivariate Discriminant –First evidence in 1.1 fb^{-1}

Single top in l+MET+(b)jets



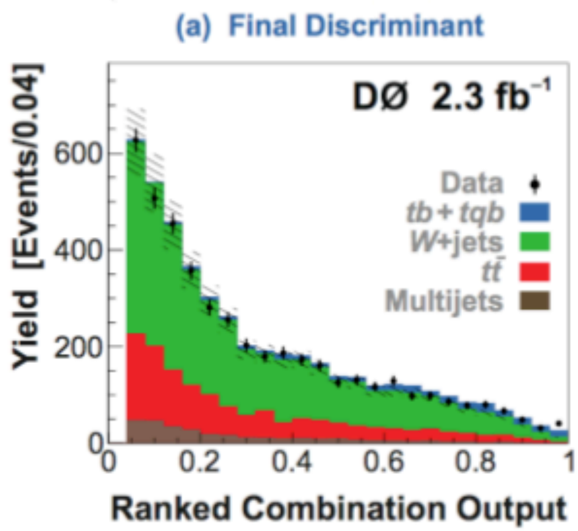
Now measure a signal smaller than WW/WZ but with (almost) the same event selection as the HW search

- require large MET and two/three(four) jets CDF(D0)
- At least one b-tagged jet
- One charged leptons (e/mu)

Simultaneous observations at CDF and D0

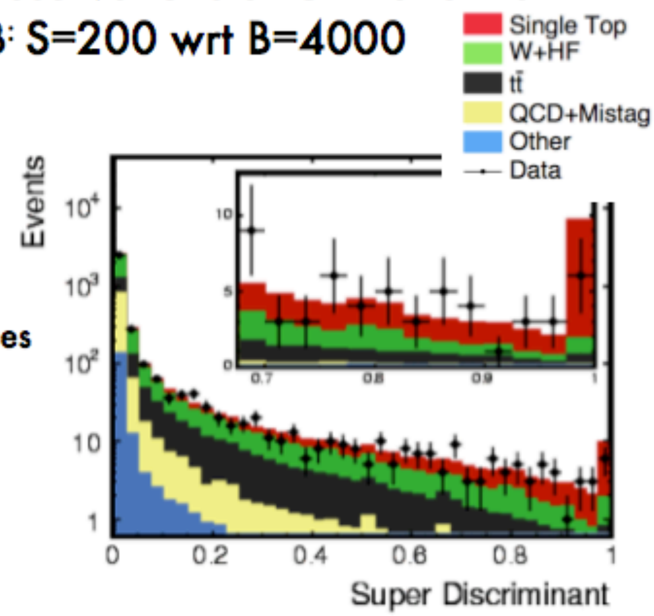
Similar S and B: S=200 wrt B=4000

Phys.Rev.Lett.103:092001,2009.



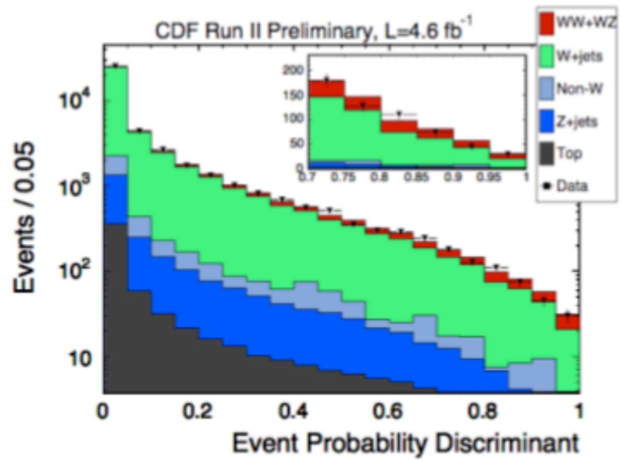
Likelihood
Neural networks
Bayesian NN
Evolutionary NN
Boosted decision trees
Matrix element

Good agreement!



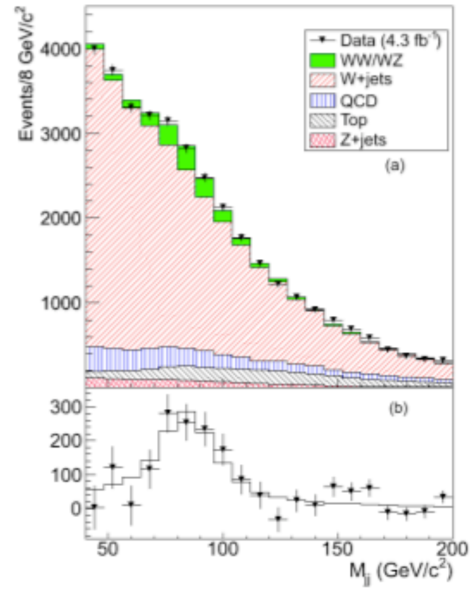
Phys. Rev. Lett. 103, 092002 (2009).

Multivariate Analyses and Mass Measurement



σ(WW+WZ)= 16.5 + 3.2 pb

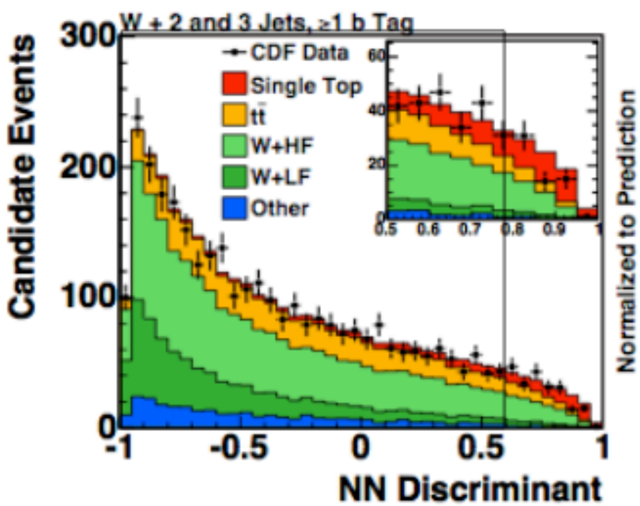
lvjj
Diboson



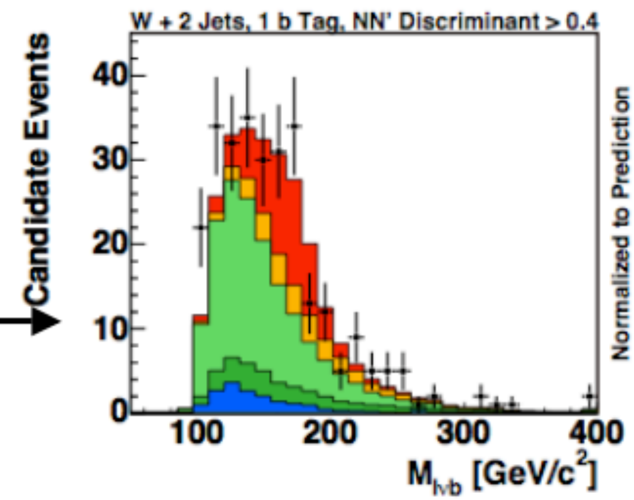
σ(WW+WZ)= 18.1 + 4.1 pb

F.
Margaroli

SM prediction of 16.1 +/- 0.9 pb.



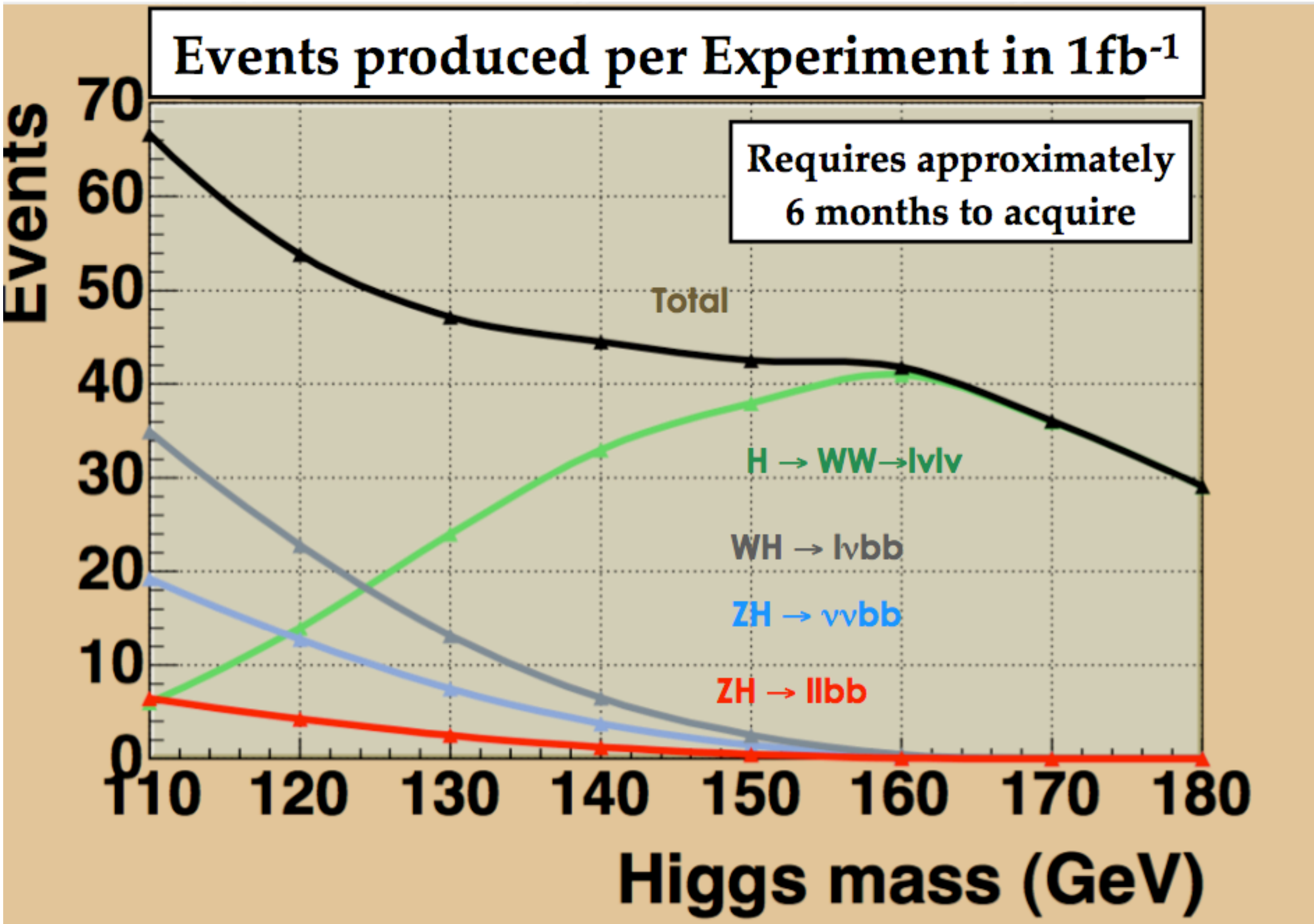
lvjj
Sinlge top



arXiv:1004.1181, submitted to PRD

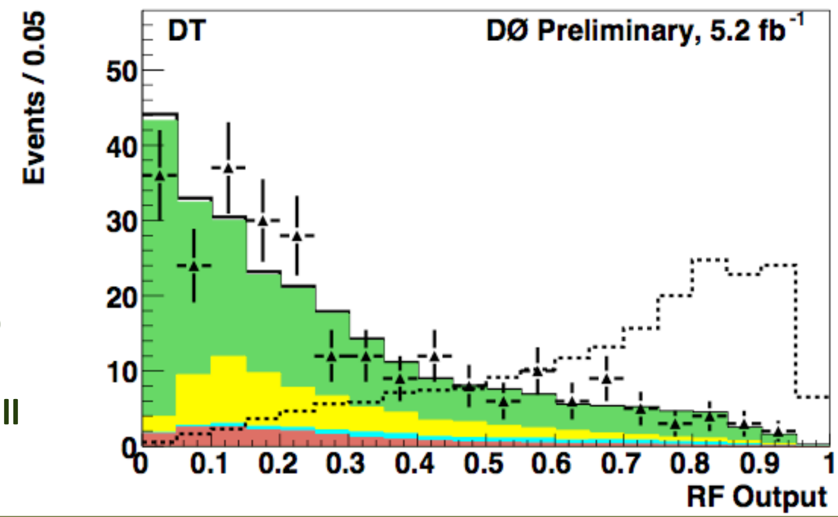
No attempt at measuring the mass, but mass peak now visible

If a SM Higgs Boson Exists (and isn't really really heavy), The Tevatron is producing it!



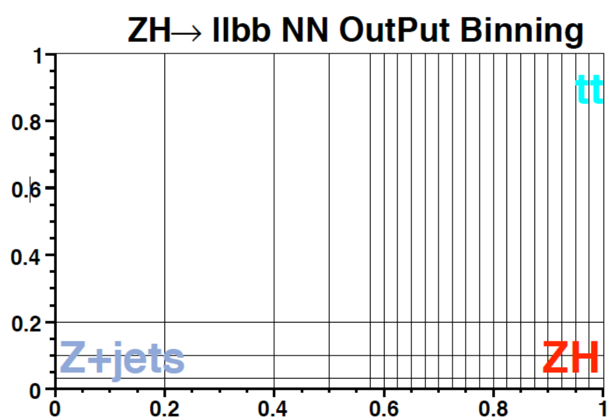
$ZH \rightarrow \ell\ell b\bar{b}$ Event Discriminants

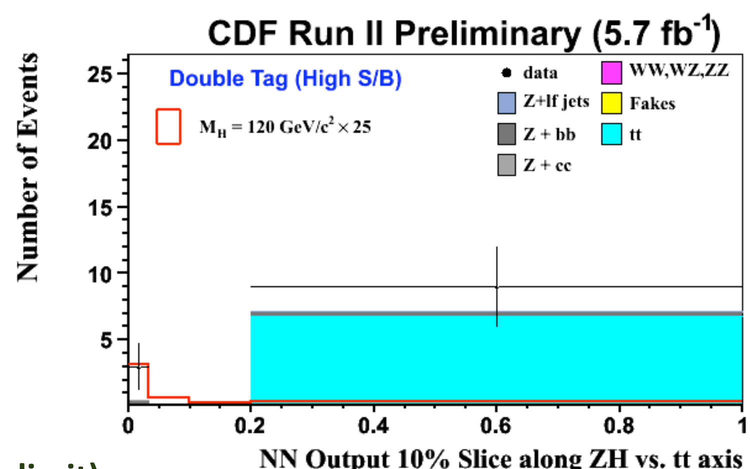
R. Hughes



D0 uses a Random Forest Decision Tree method:

- 20 well modeled inputs chosed
- 200 trees are trained, using a random subset of 10 inputs
- RF Output is the performance weighted result of all 200 trees



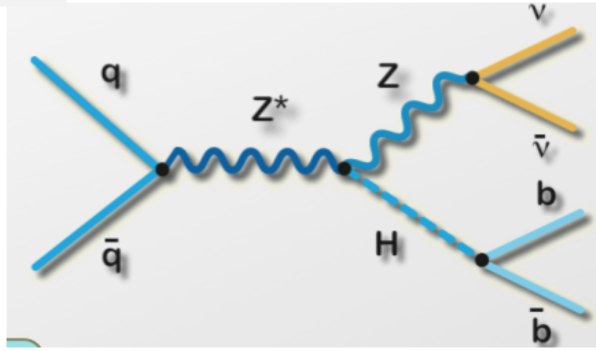


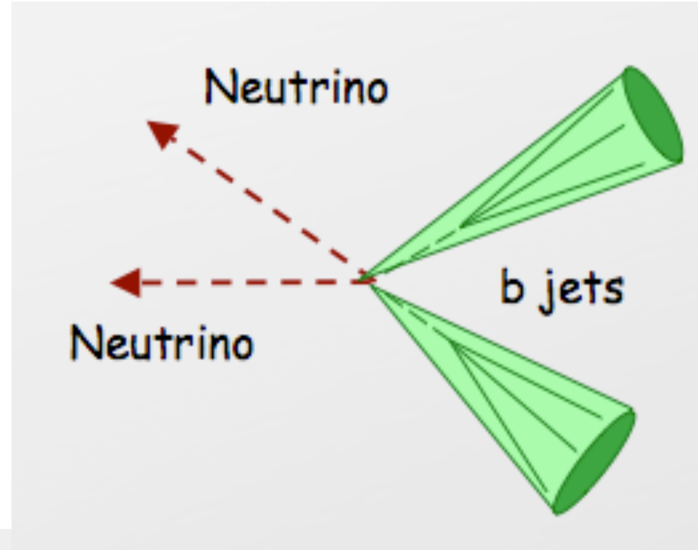
CDF uses a 2D NN:

- one axis is ZH vs Z+jets
- one axis is ZH vs ttbar
- A 10% slice along the ZH vs ttbar is for display (full 2D is used in limit)

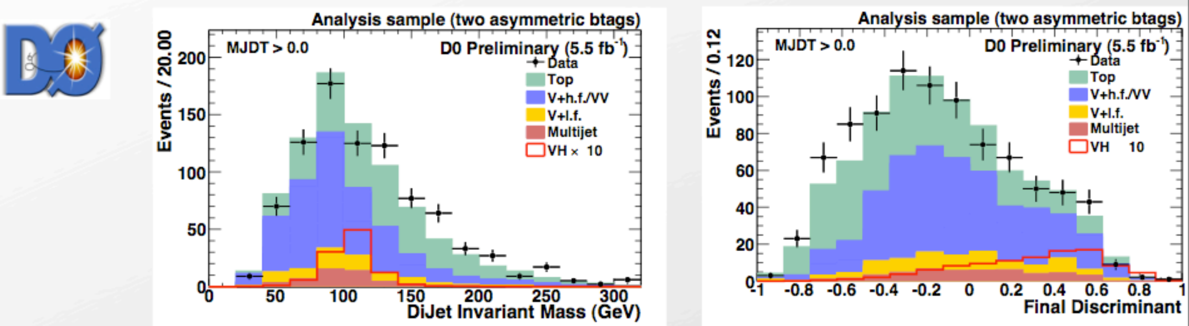
More acceptance: J. Pilot's talk

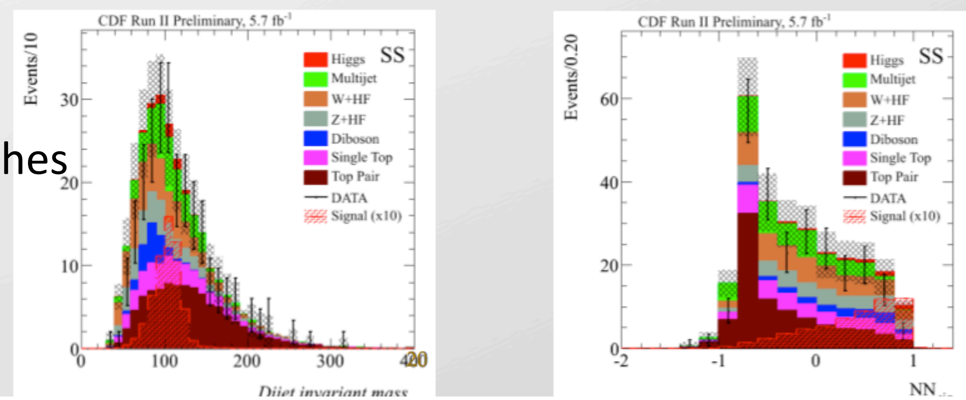
$ZH \rightarrow \nu\nu b\bar{b}$





$ZH \rightarrow \nu\nu b\bar{b}$ Event Discriminants





R. Hughes

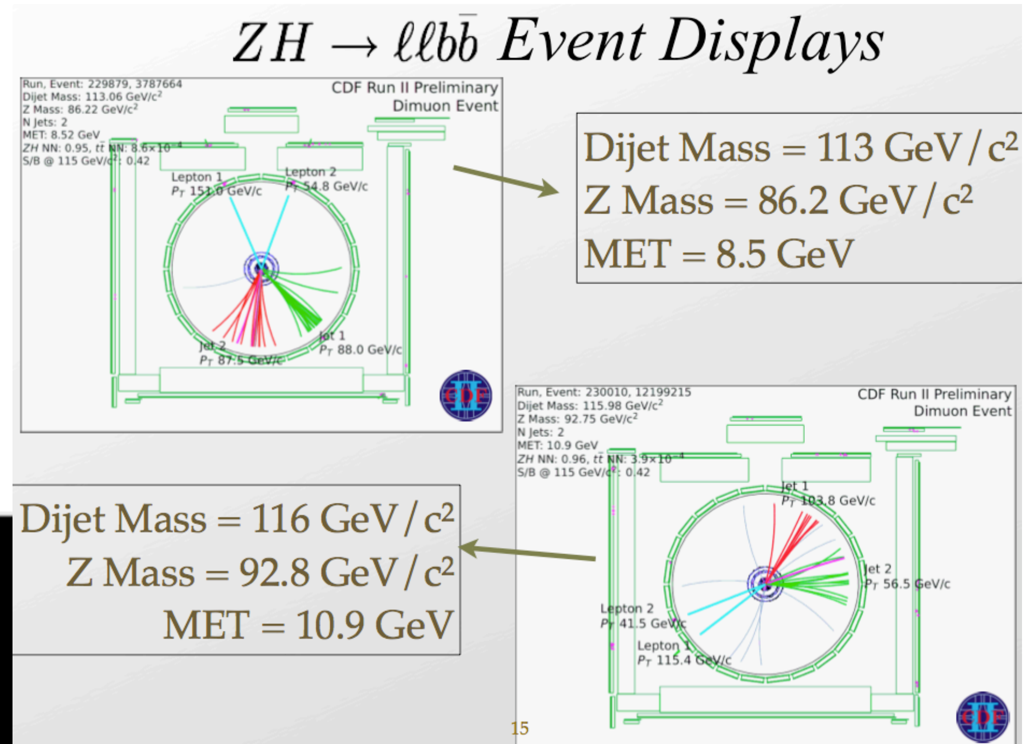
Large Multijet background – two stages of discriminants

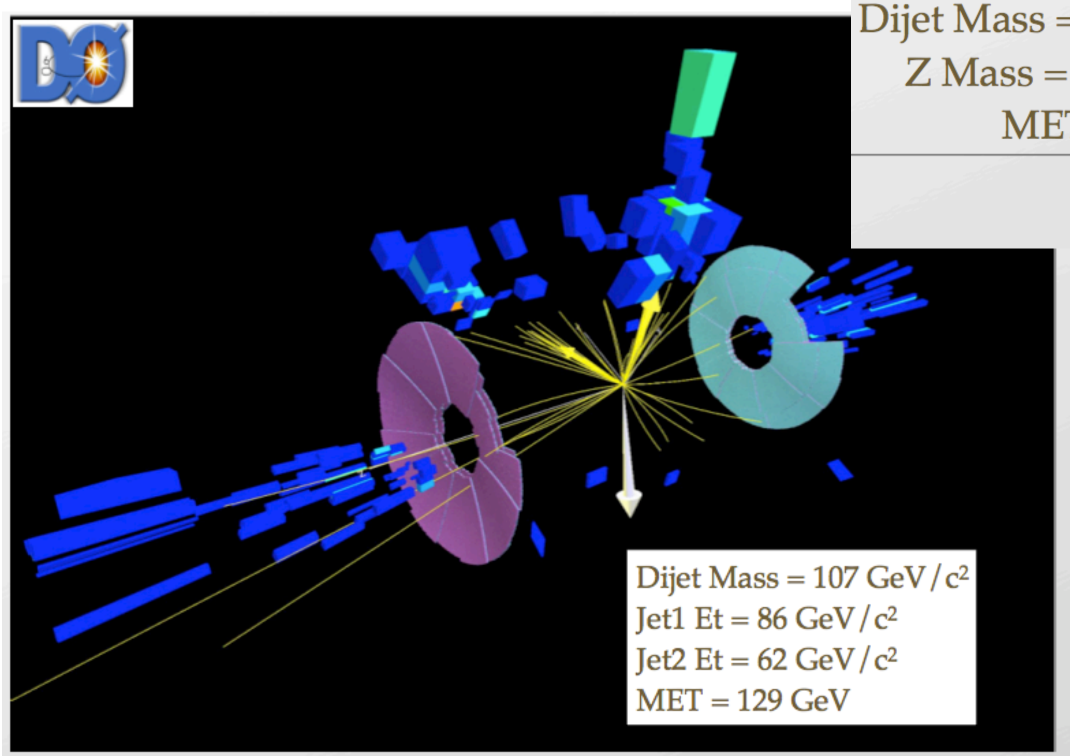
1) Anti-QCD

2) Select H from remaining backgrounds

R. Hughes

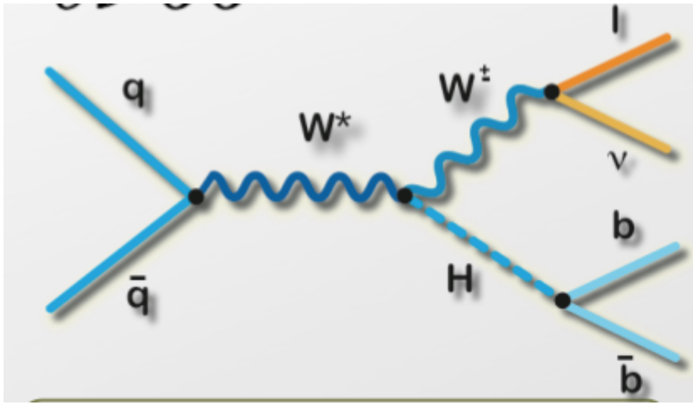
Some of the Prominent Candidates in the Low-Mass Search at the Tevatron

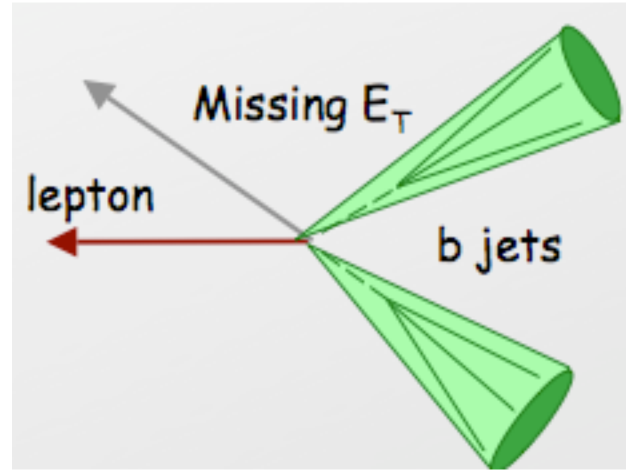




R. Hughes

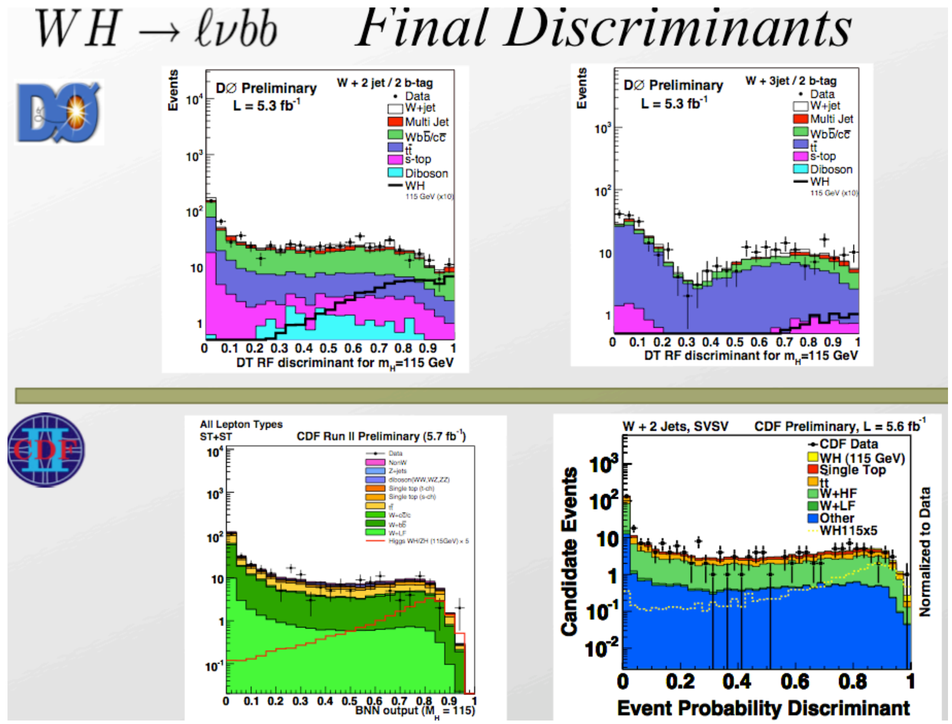
$$WH \rightarrow \ell\nu b\bar{b}$$



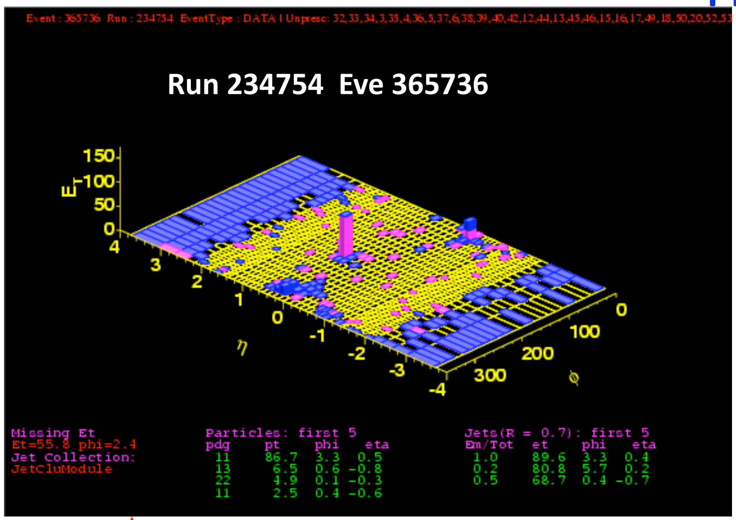


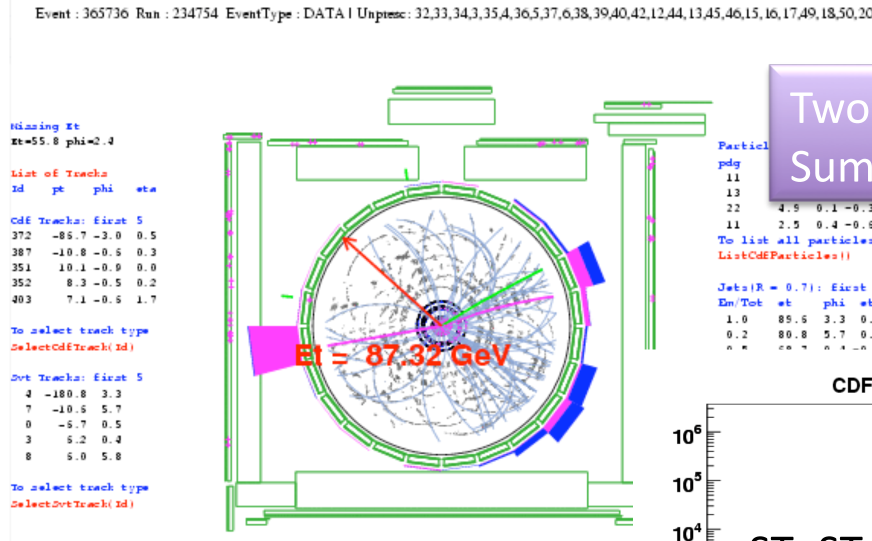
Backgrounds:
Wbb
Wcc
W+light flavor
ttbar
WW, WZ, ZZ
Single Top
Multijets

R. Hughes,
N. Huske

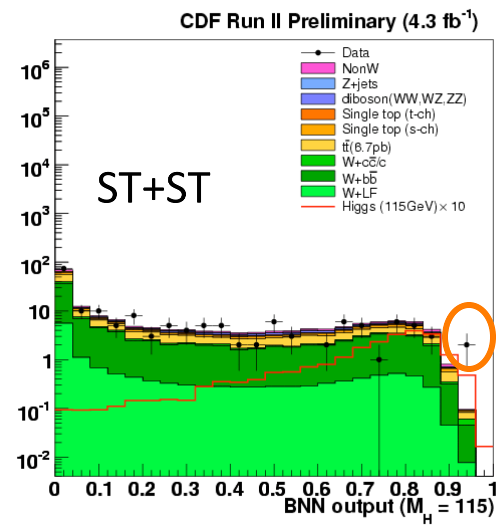


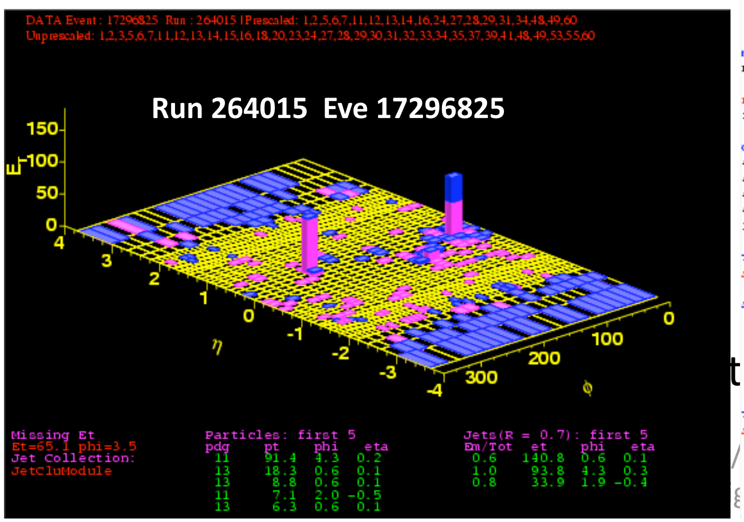
Events at m_H=115 GeV

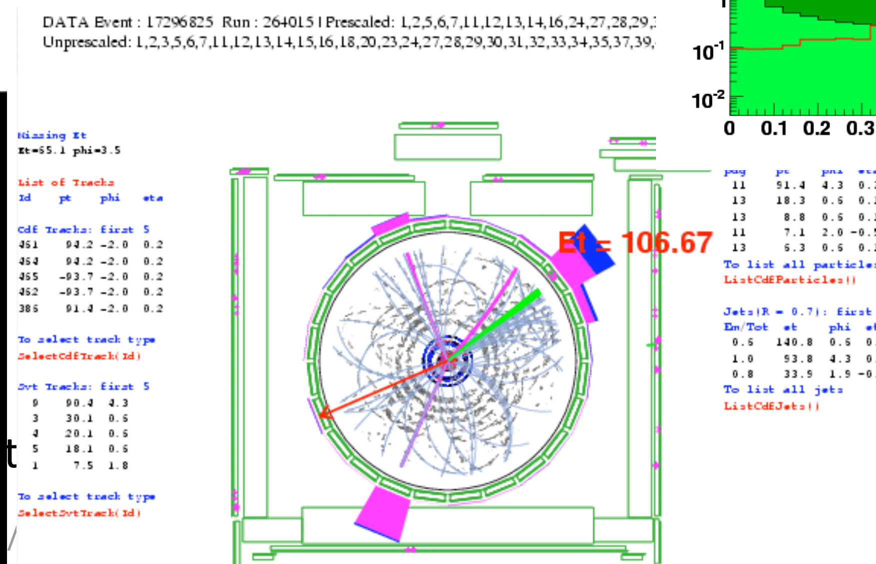




Two in WH NN, Summer 2009



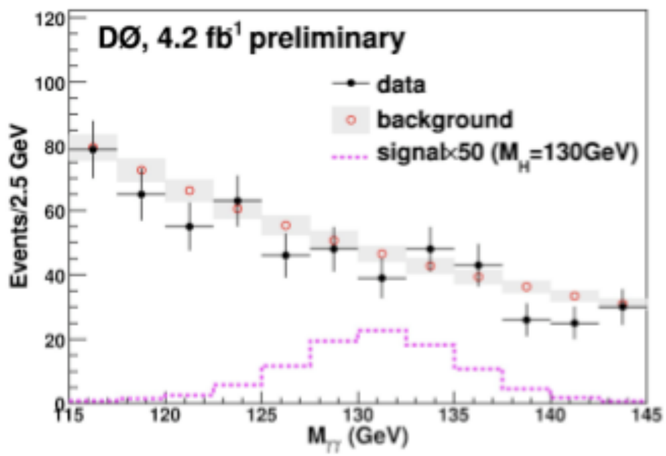


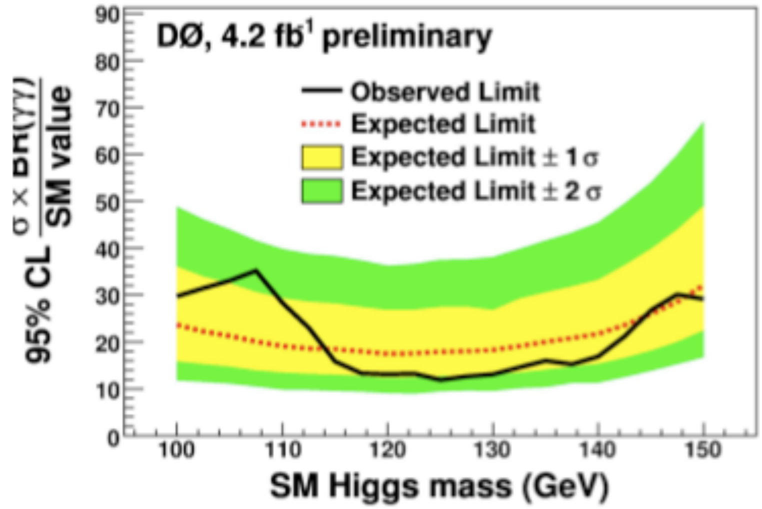


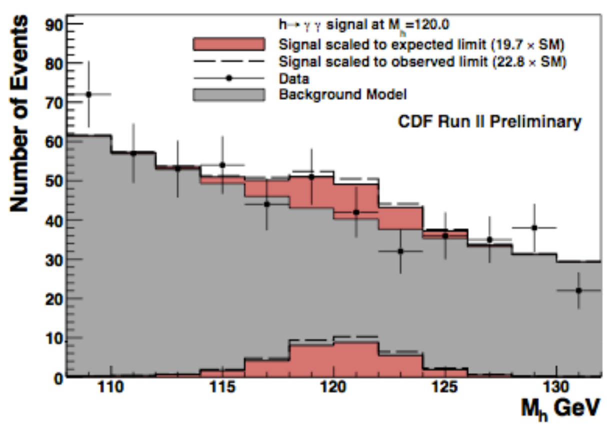
Tevatron $H \to \gamma\gamma$

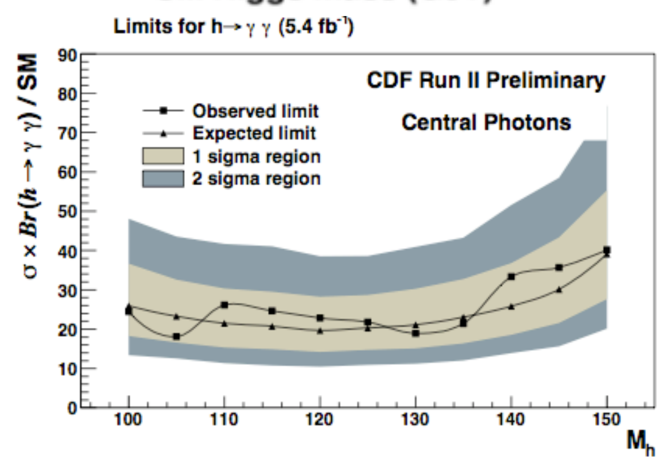
Diphoton mass bump-hunt

Uses all production mechanisms ggH, WH, ZH, VBF







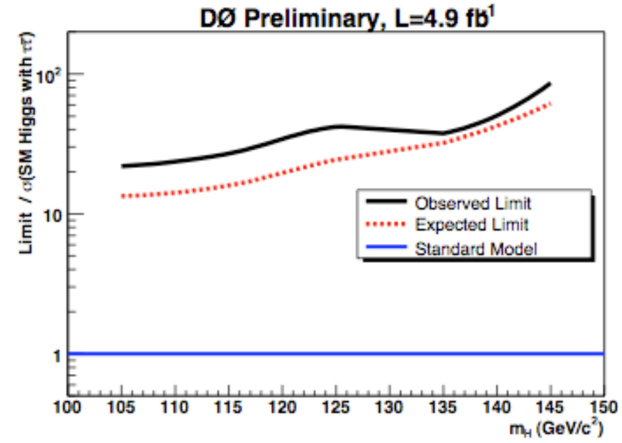


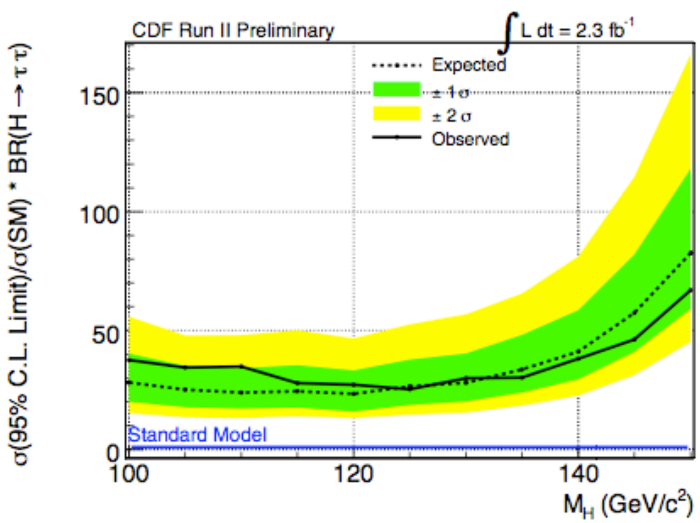
S. Chakrabarti

$H \rightarrow \tau\tau$ + 2 Jets

- W(→ qq') H(→ τ+τ-)
- Z(→ qq) H(→ τ+τ-)
- H(→ bb) Z(→ τ+τ-)
- VBF qHq' → q' τ+τ-q
- gg → H → τ+τ-+≥ 2jets

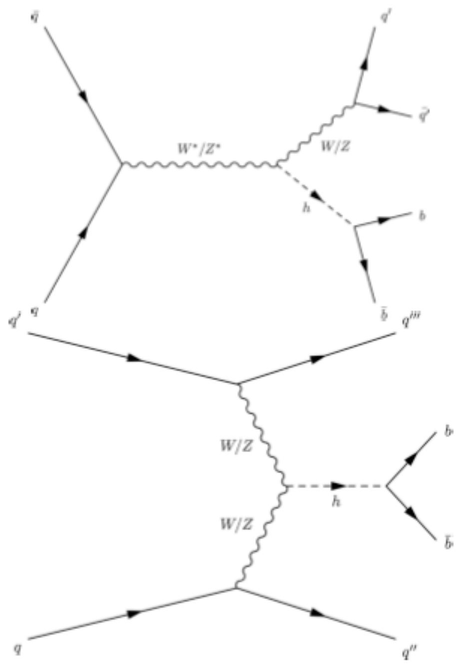
S. Chakrabarti

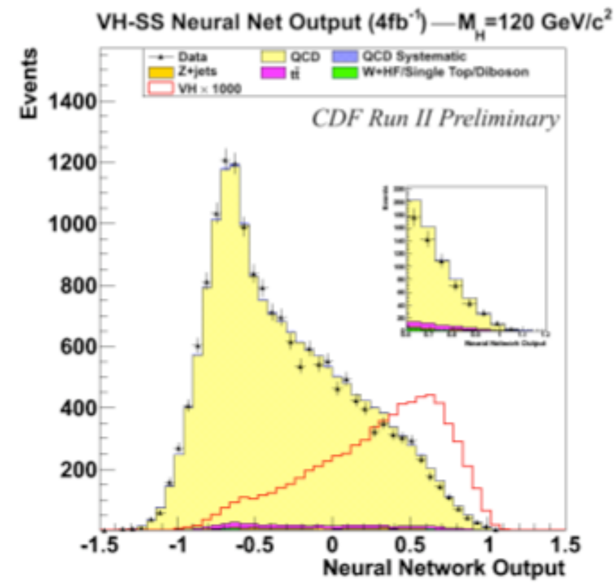




WH, ZH → qqbb

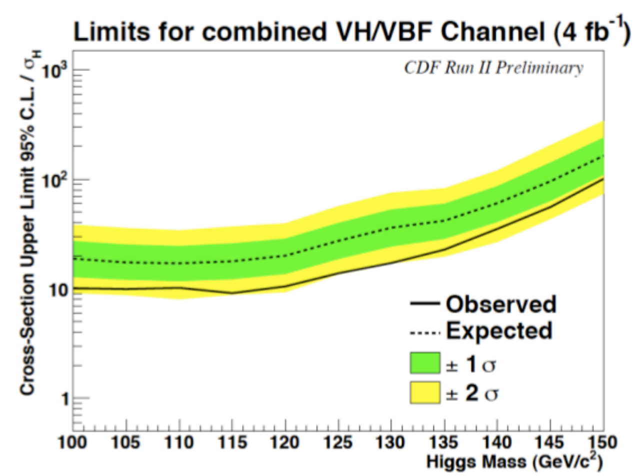
- Large signal yield as it profits from the largest cross-section x branching ratio
- Complete event information. No missing energy to infer
- large QCD background





Signal x 1000! Large Multijet Background

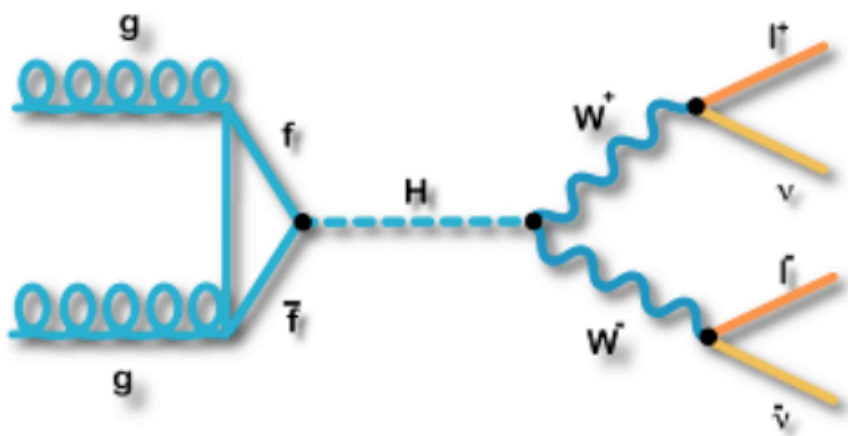
Still expect to set limits ~20 x SM rate



S. Chakrabarti

High-Mass SM Tevatron Searches

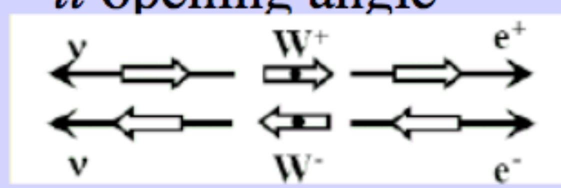
$H \rightarrow WW \rightarrow l^+ \nu l^- \nu$ Signature



Really the dominant
search mode above 125 GeV

- leptonic W decays
- opposite charge
- large missing transverse energy

- Kinematic Discriminants
  - *ll* opening angle



  - kinematics input MVA

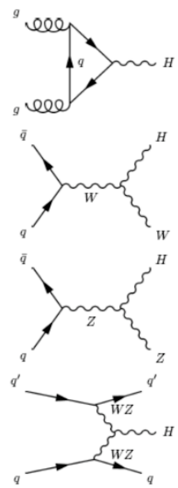
M. Kirby

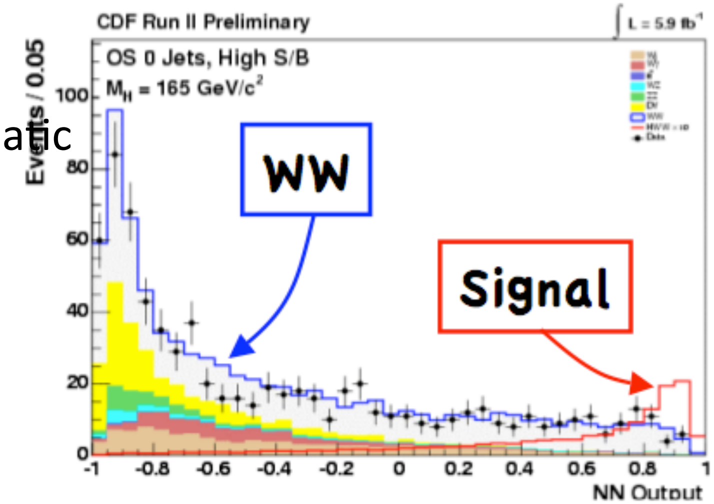
Analysis Strategy: Divide into jet categories
(also separate out like-sign dileptons, trileptons, and taus because signals, backgrounds, and systematic uncertainties are different)

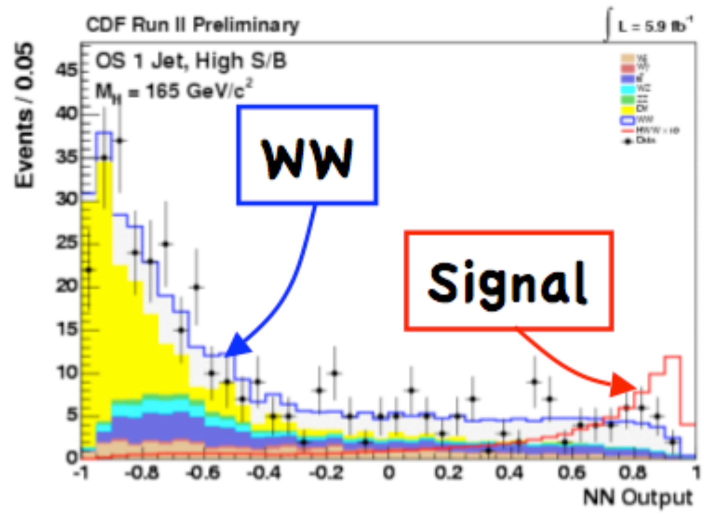
0 Jet Events

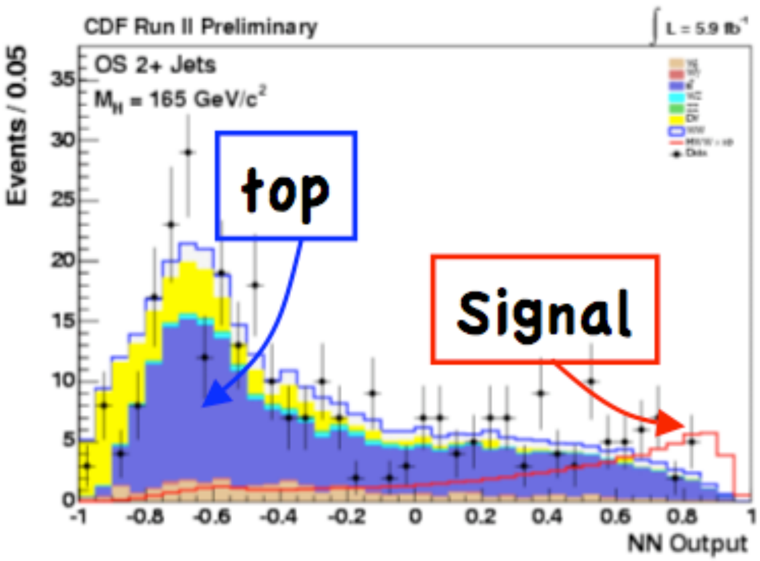
1 Jet Events

2+ Jet Events







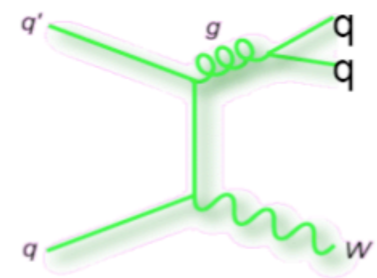


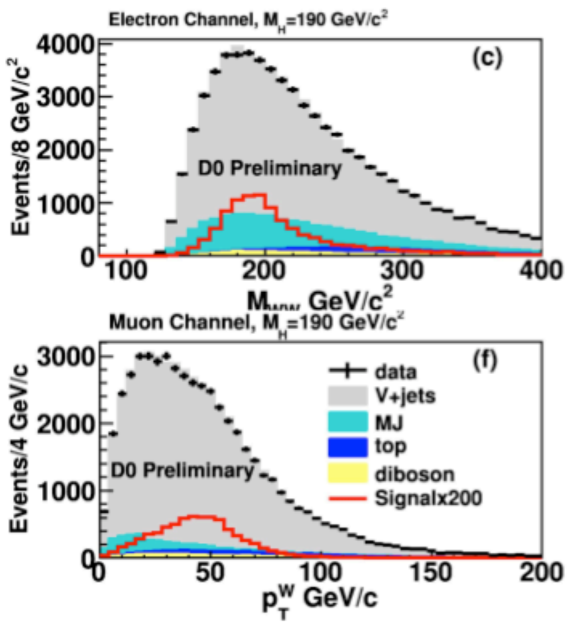
M. Kirby

New Channels Are Always Being Added

$H \to WW \to l\nu jj$

- Event selection
  - high-p_T lepton > 15 GeV
  - large missing E_T > 15 GeV
  - 2 high-p_T jets





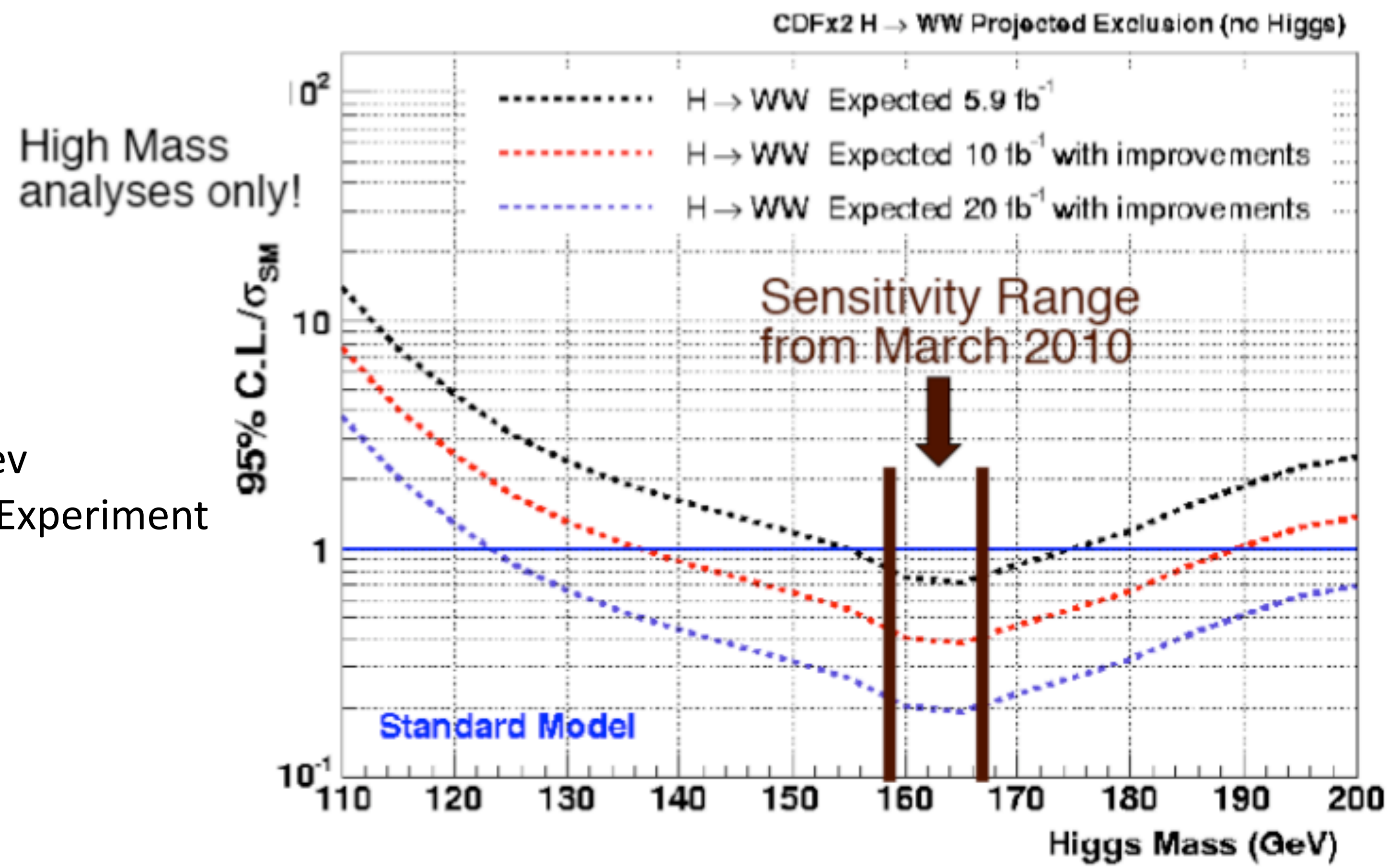
- background composition
  - W+2 jets
  - top production
  - Diboson - WW, WZ, ZZ
  - QCD multijet events
- utilize techniques from low mass analyses

M. Kirby

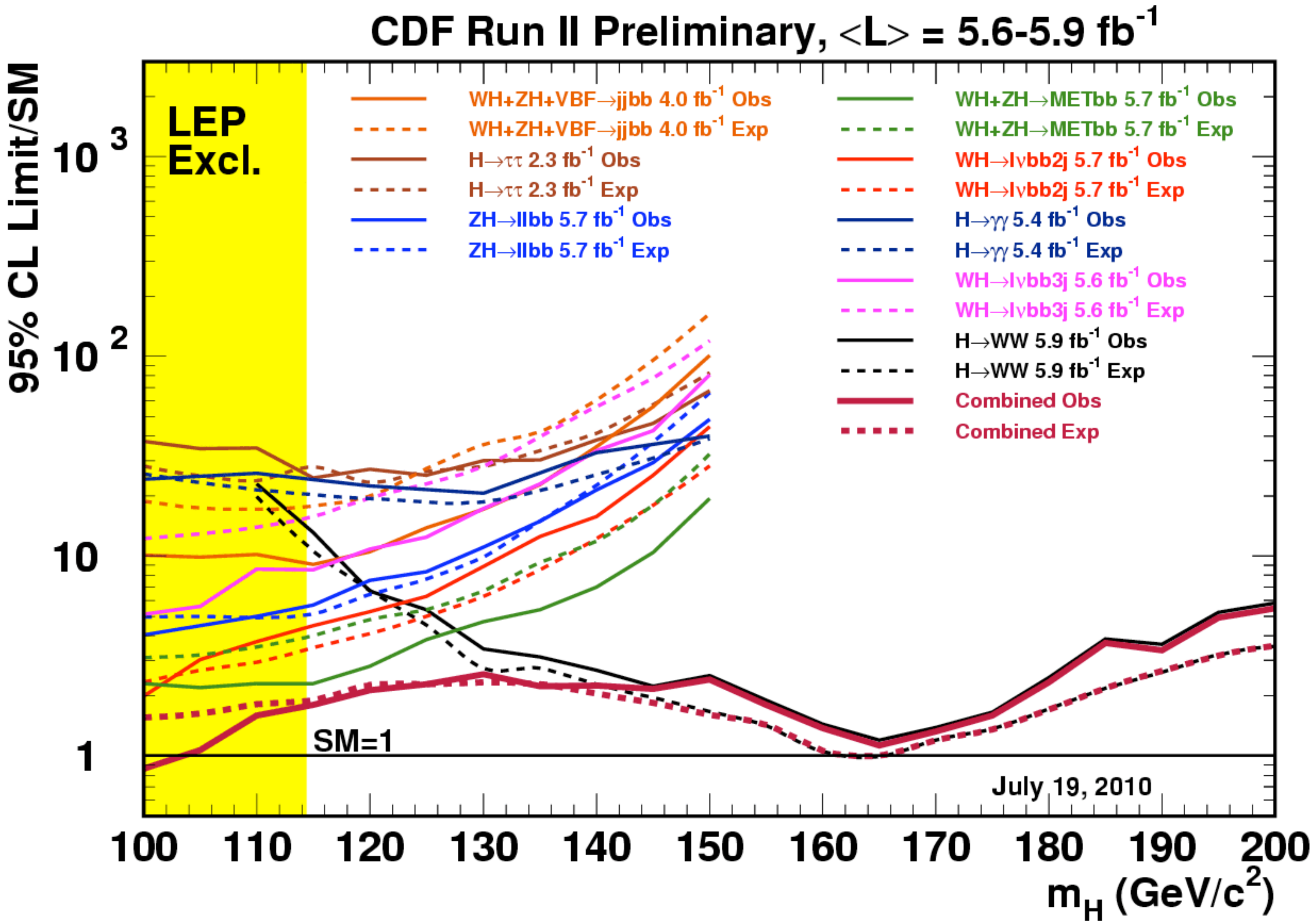
Tevatron H→WW Projections

137—190 Gev
with 10 fb^{-1}/Experiment

M. Kirby

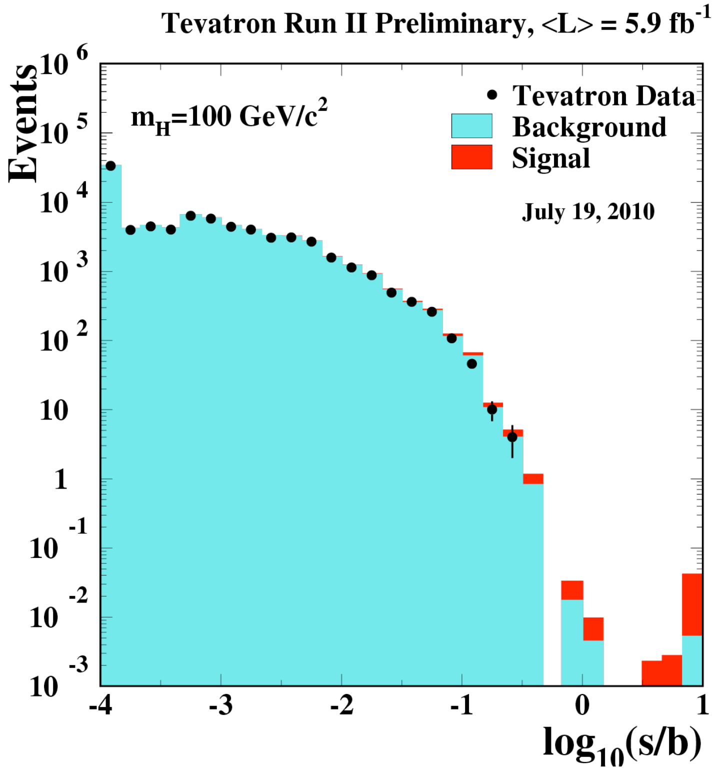


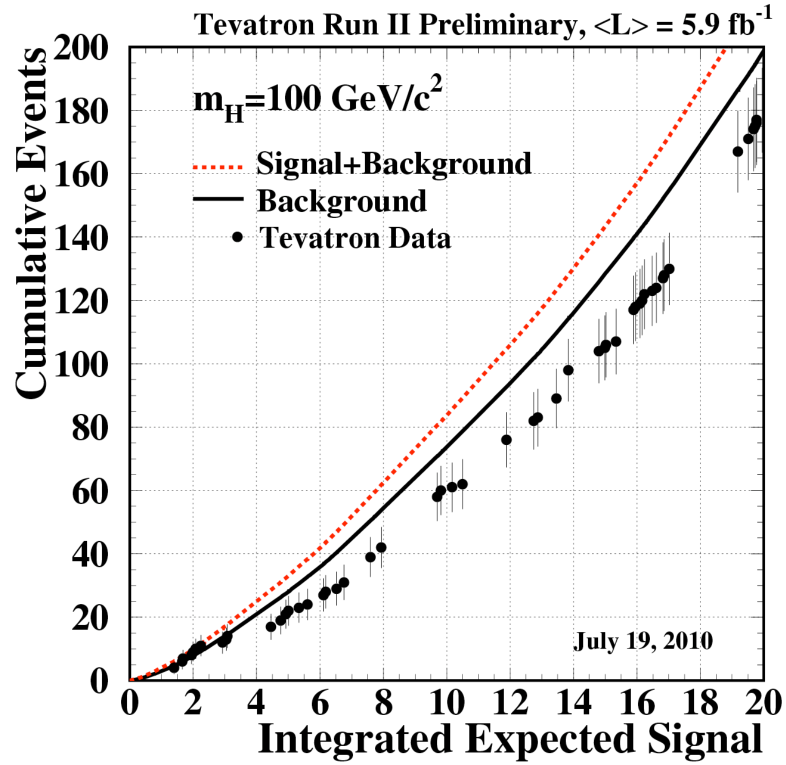
assumes two experiments with equal sensitivity

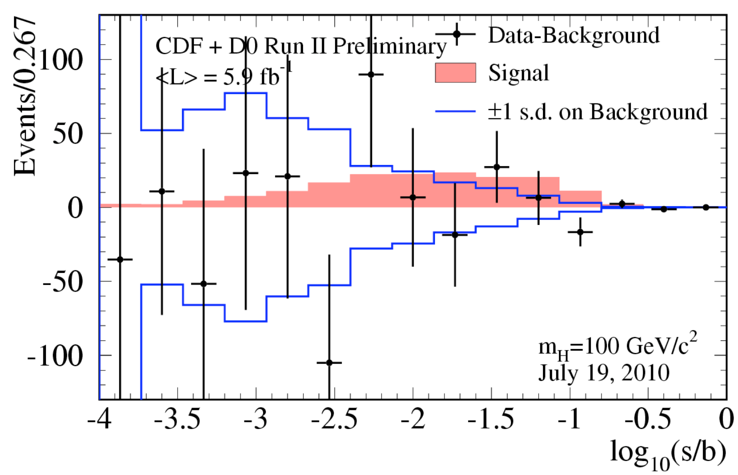


CDF Run II Preliminary, <L> = 5.6-5.9 fb^{-1}
95% CL Limit/SM
LEP Excl.
WH+ZH+VBF→jjbb 4.0 fb^{-1} Obs
WH+ZH+VBF→jjbb 4.0 fb^{-1} Exp
H→ττ 2.3 fb^{-1} Obs
H→ττ 2.3 fb^{-1} Exp
ZH→llbb 5.7 fb^{-1} Obs
ZH→llbb 5.7 fb^{-1} Exp
WH+ZH→METbb 5.7 fb^{-1} Obs
WH+ZH→METbb 5.7 fb^{-1} Exp
WH→lνbb2j 5.7 fb^{-1} Obs
WH→lνbb2j 5.7 fb^{-1} Exp
H→γγ 5.4 fb^{-1} Obs
H→γγ 5.4 fb^{-1} Exp
WH→lνbb3j 5.6 fb^{-1} Obs
WH→lνbb3j 5.6 fb^{-1} Exp
H→WW 5.9 fb^{-1} Obs
H→WW 5.9 fb^{-1} Exp
Combined Obs
Combined Exp
SM=1
July 19, 2010
m_H (GeV/c^2)

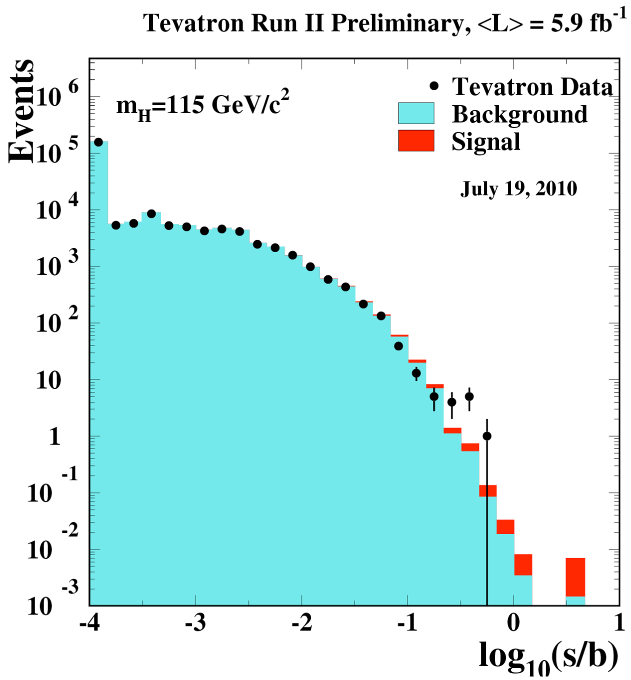
T. Junk

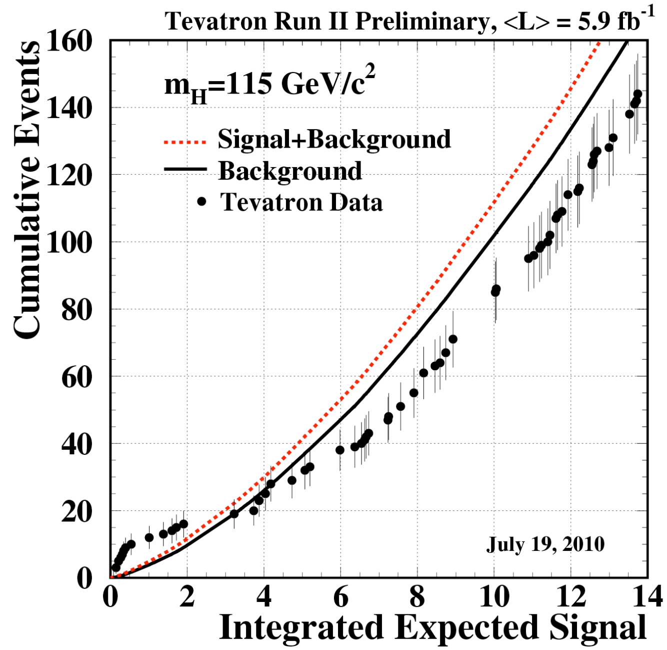

Tevatron Run II Preliminary, <L> = 5.9 fb-1
Events
mH=100 GeV/c2
Tevatron Data
Background
Signal
July 19, 2010
log10(s/b)


Tevatron Run II Preliminary, <L> = 5.9 fb-1
Cumulative Events
mH=100 GeV/c2
Signal+Background
Background
Tevatron Data
July 19, 2010
Integrated Expected Signal

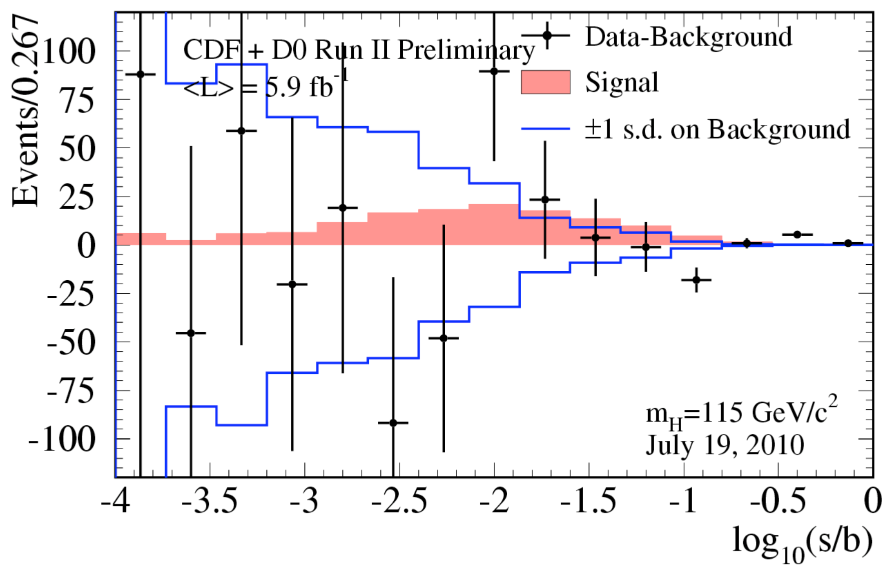

CDF + D0 Run II Preliminary
<L> = 5.9 fb-1
Data-Background
Signal
±1 s.d. on Background
Events/0.267
mH=100 GeV/c2
July 19, 2010
log10(s/b)

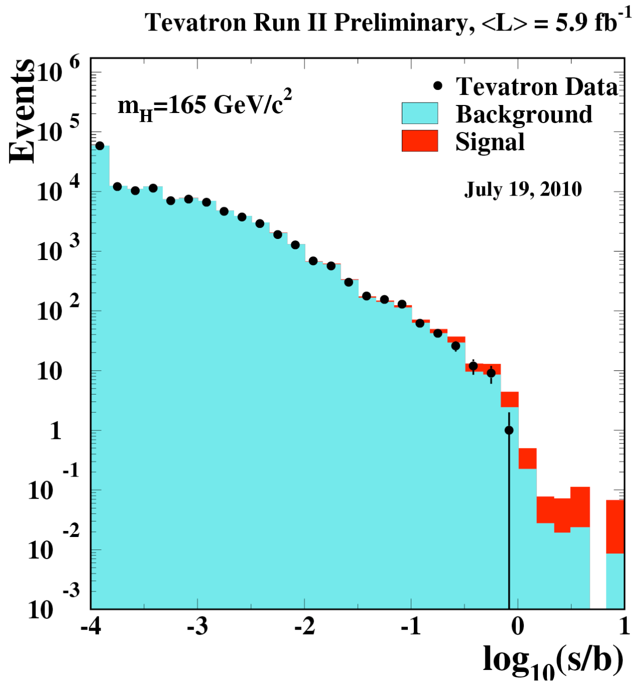
T. Junk

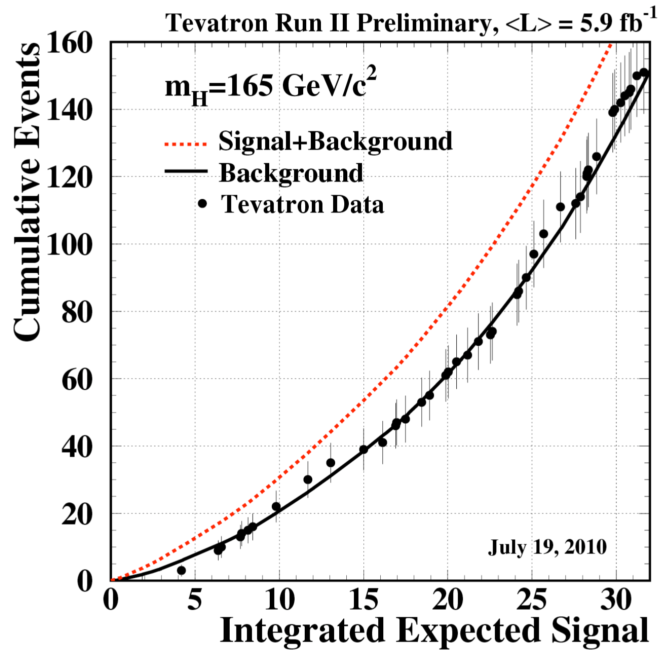

Tevatron Run II Preliminary, <L> = 5.9 fb-1
Events
mH=115 GeV/c2
Tevatron Data
Background
Signal
July 19, 2010
log10(s/b)


Tevatron Run II Preliminary, <L> = 5.9 fb-1
Cumulative Events
mH=115 GeV/c2
Signal+Background
Background
Tevatron Data
July 19, 2010
Integrated Expected Signal

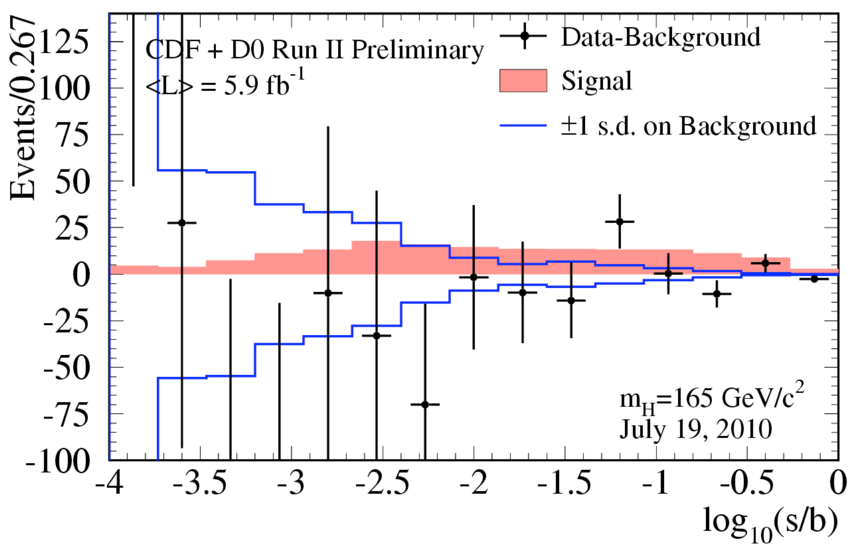
T. Junk


CDF + D0 Run II Preliminary
<L> = 5.9 fb-1
Data-Background
Signal
±1 s.d. on Background
Events/0.267
mH=115 GeV/c2
July 19, 2010
log10(s/b)


Tevatron Run II Preliminary, <L> = 5.9 fb-1
Events
mH=165 GeV/c2
Tevatron Data
Background
Signal
July 19, 2010
log10(s/b)

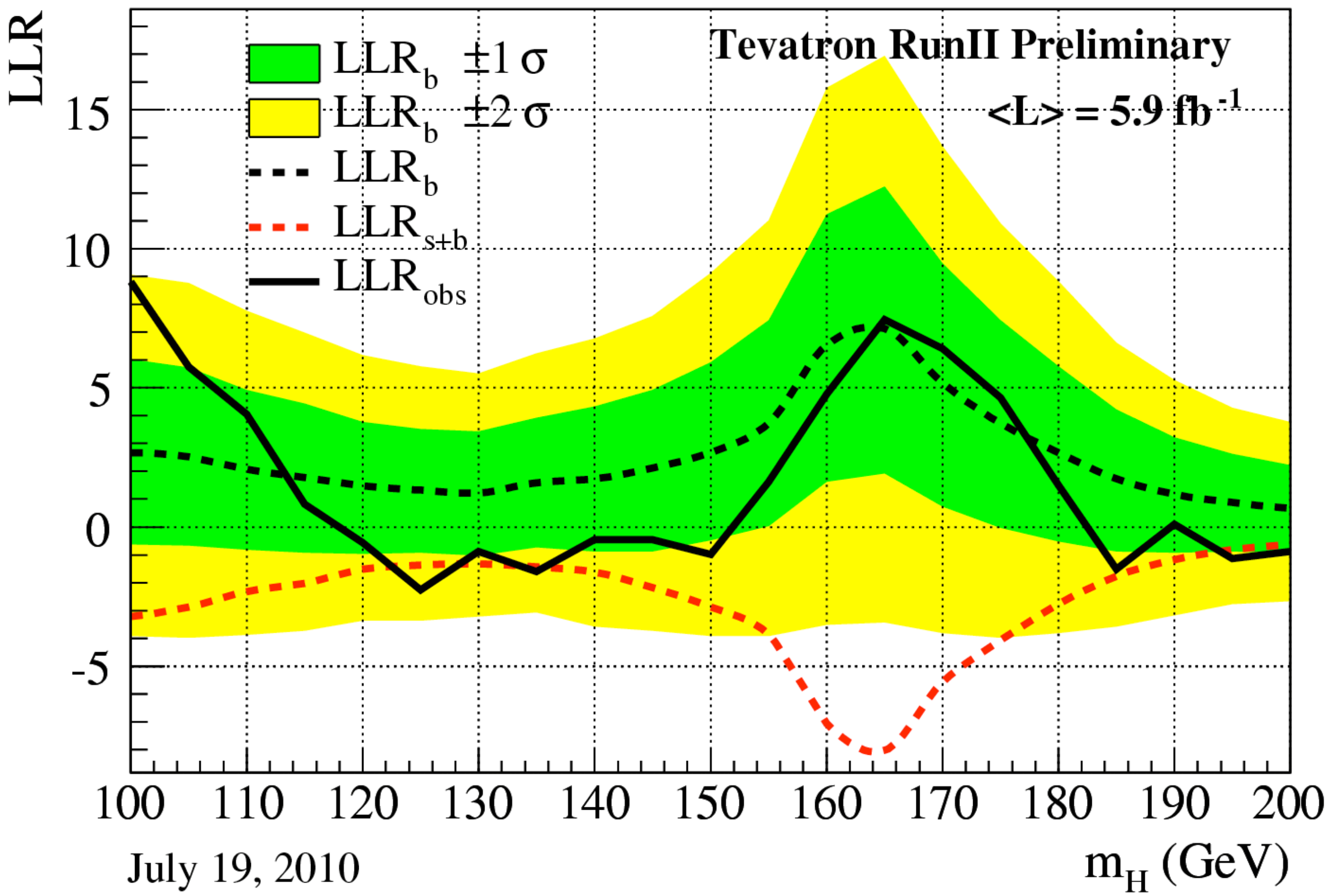

Tevatron Run II Preliminary, <L> = 5.9 fb-1
Cumulative Events
mH=165 GeV/c2
Signal+Background
Background
Tevatron Data
July 19, 2010
Integrated Expected Signal

T. Junk

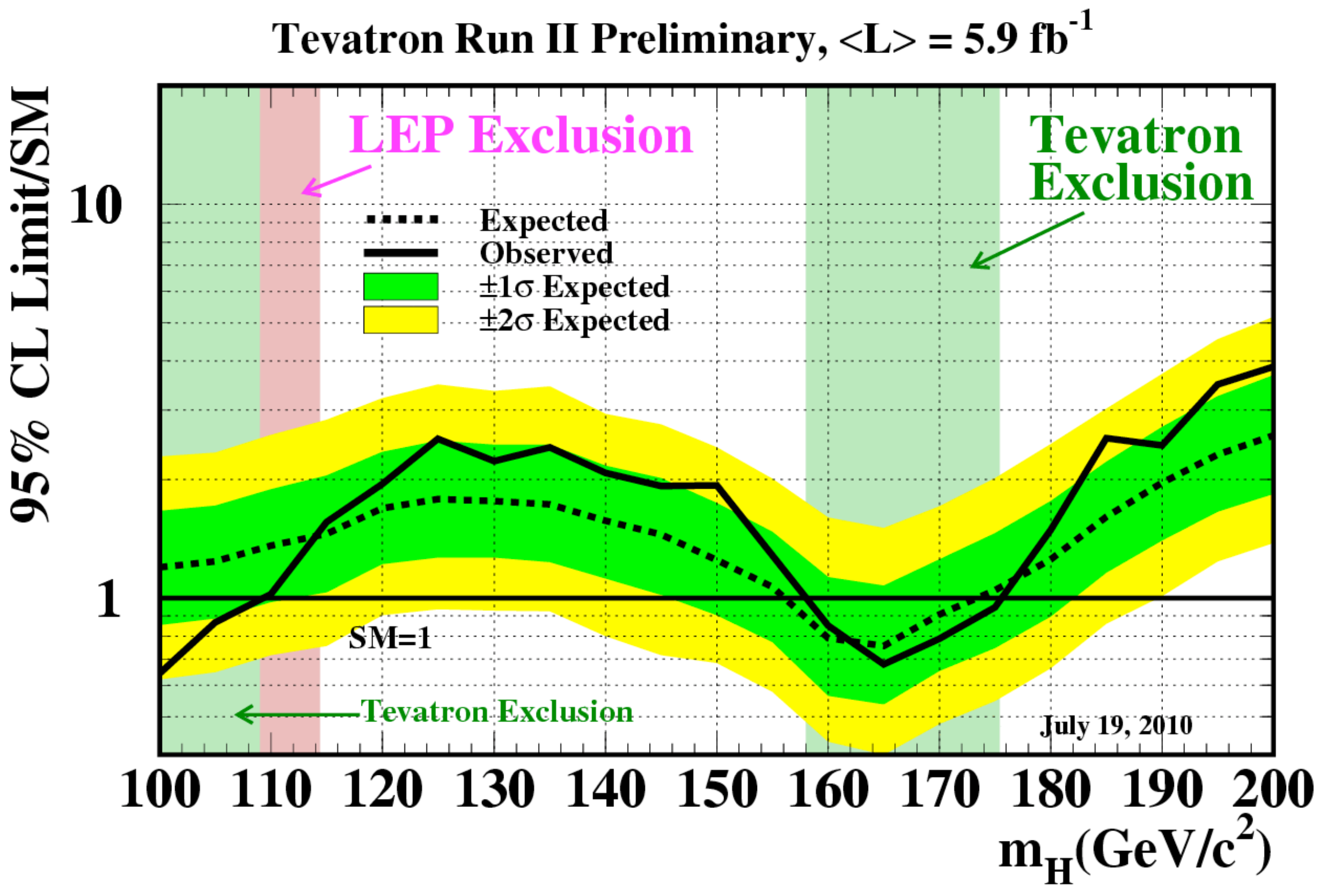

CDF + D0 Run II Preliminary
<L> = 5.9 fb-1
Data-Background
Signal
±1 s.d. on Background
Events/0.267
mH=165 GeV/c2
July 19, 2010
log10(s/b)

Looking for a Hint of a Signal

$$-2\ln Q \equiv LLR \equiv -2\ln\left(\frac{L(\text{data}\mid s+b,\hat{\theta})}{L(\text{data}\mid b,\hat{\hat{\theta}})}\right)$$



Tevatron Observed and Expected Limits



Bayesian

Excluded regions:

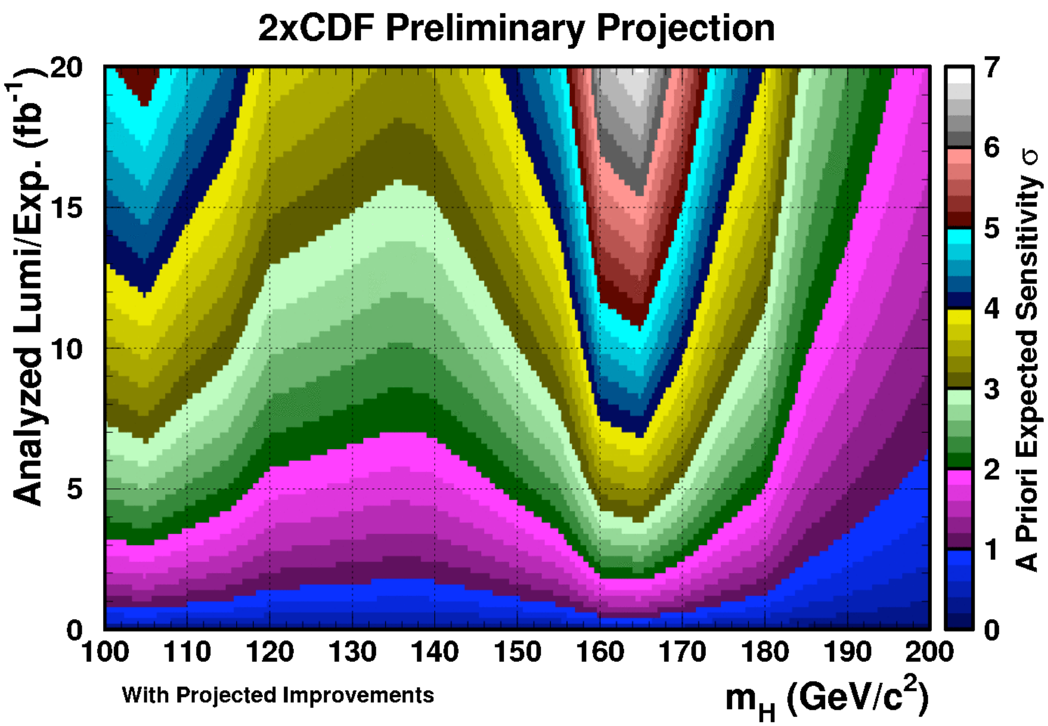
158 < m_H < 175 GeV

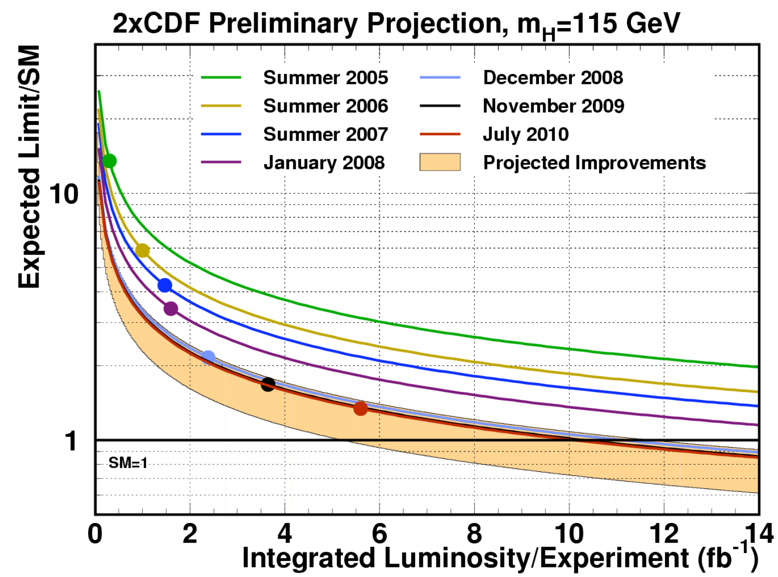
100 < m_H < 109 GeV

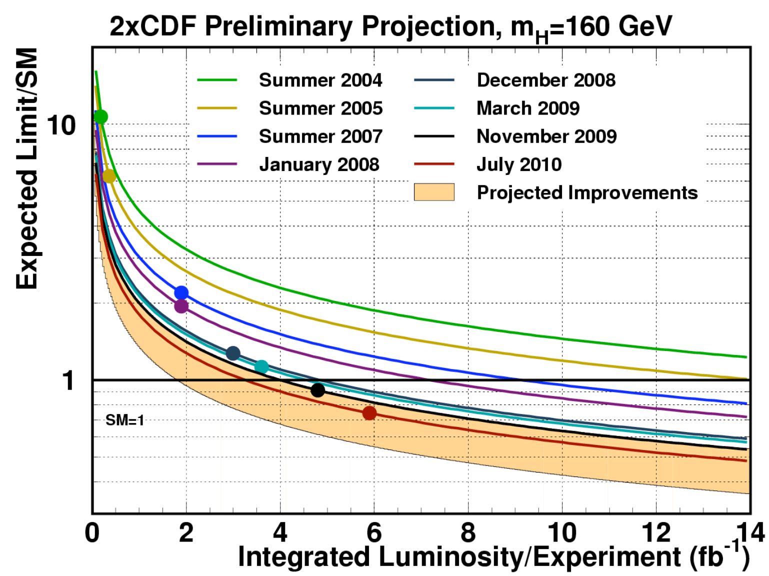
Expected Exclusion
(if no signal is present):

156 < m_H < 173 GeV

Tevatron Projected Performance







We continue to improve our analyses
as well as collect more data.

Multivariate analyses are pretty much at their limit: We now seek more acceptance, looser requirements, new channels...

Algorithm improvements: b-tagging

Improved b-tagging algorithms (b vs light jet discrimination)

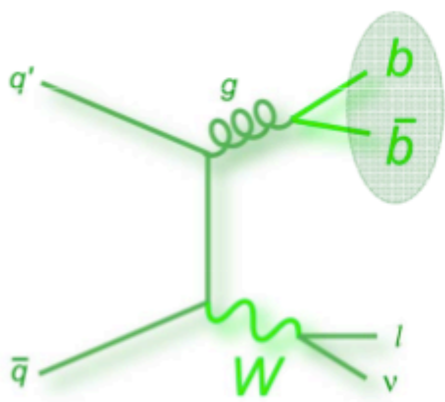
~10% increase in b-jet efficiency at same fake rate

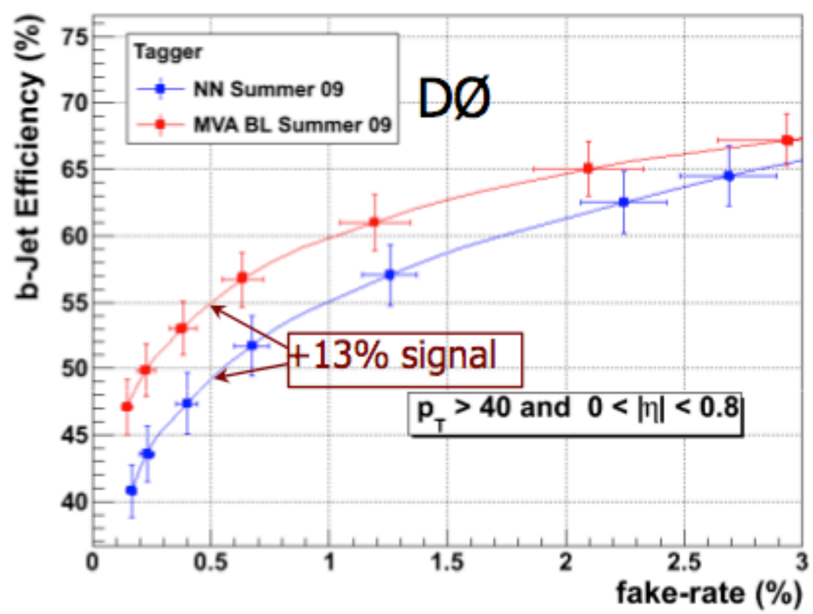
New, additional algorithms

-b vs. c discrimination

-b vs. bb (merged) discrimination

Not yet in recent Higgs results





G. Bernardi

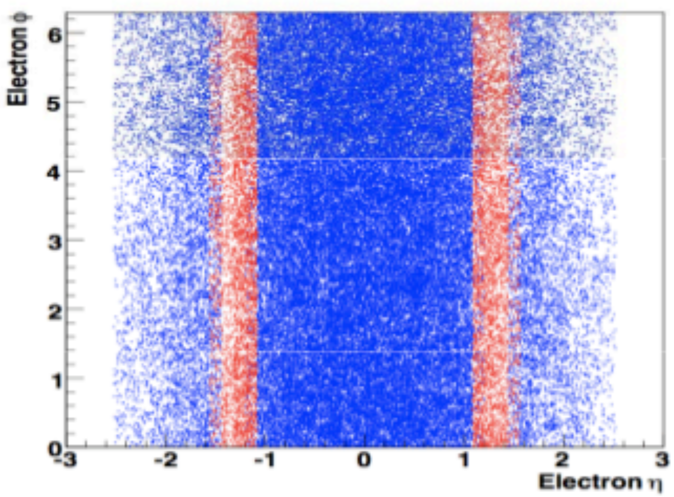
Signal Acceptance

G. Bernardi

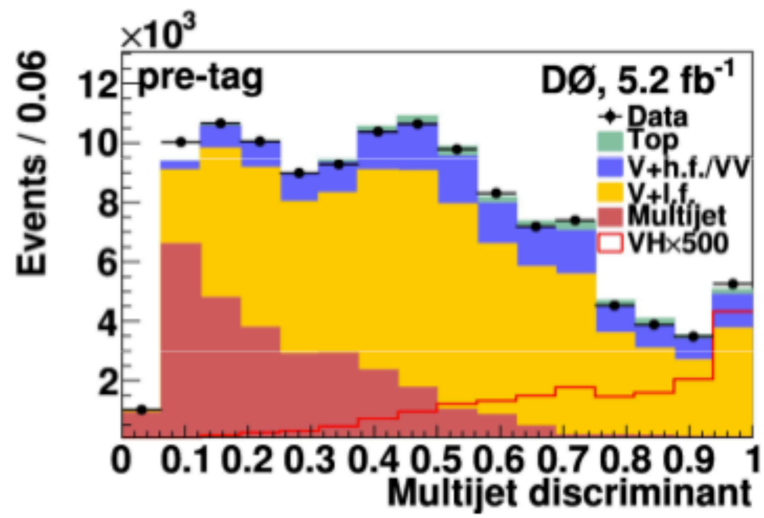
Continue to work to maximize signal acceptance

Example: ZH channels

Electrons in inter calorimeter regions



Replace several cuts on kinematic variables by cut on discriminant



mu+track

Already got ~8% increase in signal yields per lepton

➔ sensitivity improvement

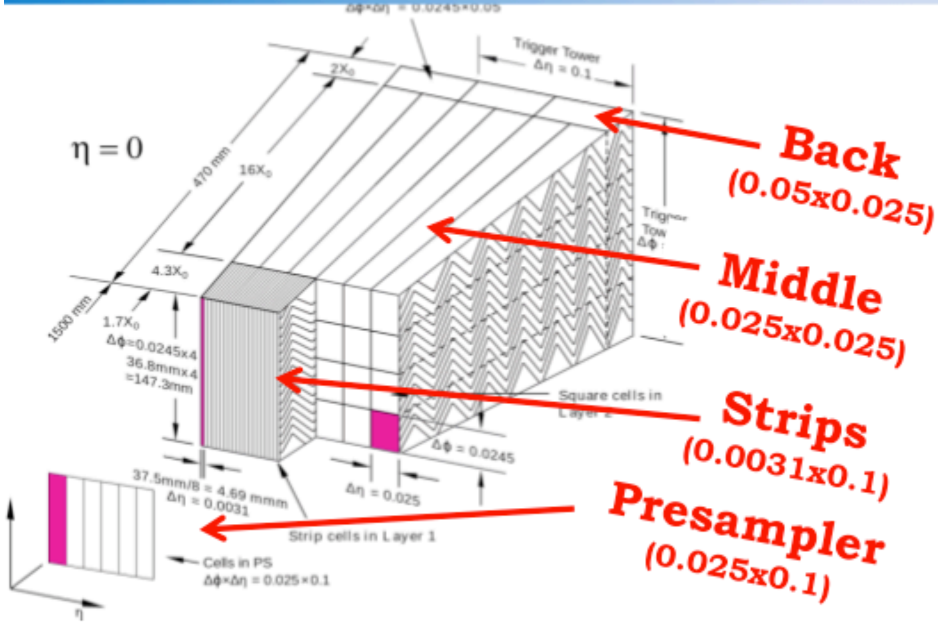
LHC: First Data – Performance and Benchmark Processes

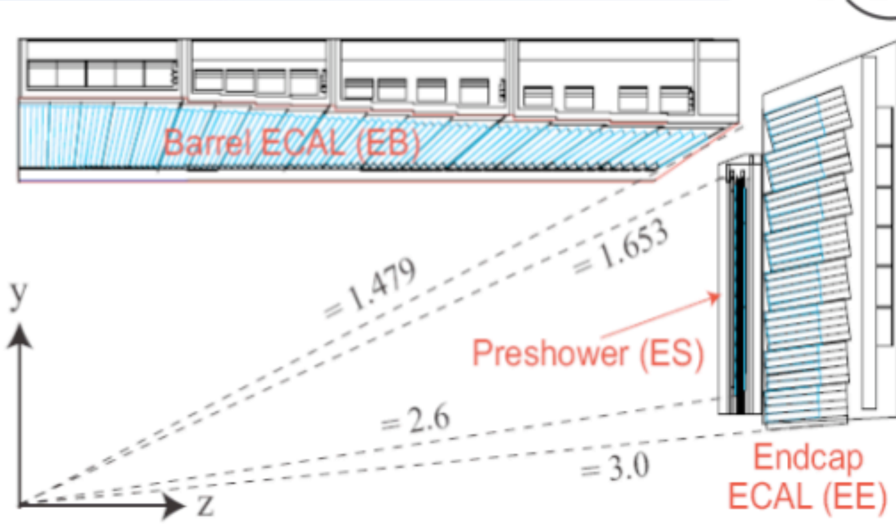
- Both LHC Experiments must "Rediscover the Standard Model" In order to back up Higgs and New Physics Searches

- Calibrations are needed for:
  - Trigger efficiency for leptons (later, high-E_T jets, MET, ...)
  - Lepton ID efficiency (electrons, muons, taus)
  - Photon ID efficiency
  - Photon Energy scale / linearity
  - Lepton energy scale / linearity
  - Jet Energy scale / linearity

Photons: M. Aurousseau, N. Chanon
Jets: J. Schaarschmidt
Muons: R. Wilken
B and τ Tagging: M. Bluj

Lepton and Missing E_T Performance Summary: C. Ochando





- Pb + LAr sampling calorimeter
- 3 radial layers + pre-shower
- Design energy resolution :

$$\frac{E}{E} \quad \frac{10\%}{\sqrt{E}} \oplus \frac{300\,\mathrm{MeV}}{\mathrm{E}} \oplus 0.7\%$$

- Outside solenoid coil

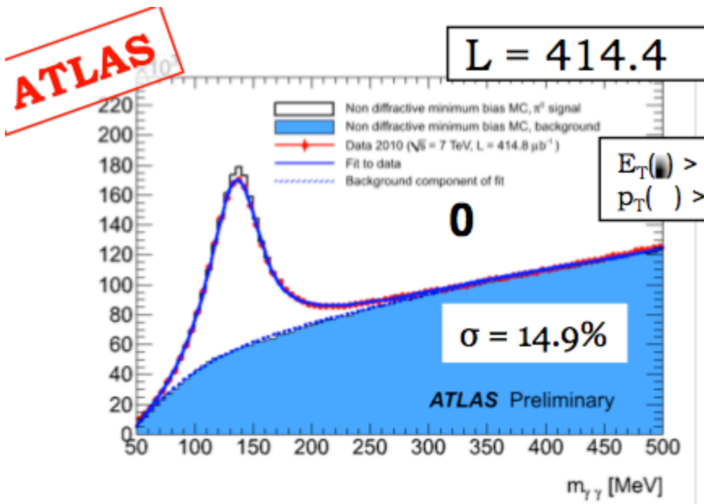
- $PbWO_4$ scintillating crystals
- Preshower in front of EE
- Design energy resolution :

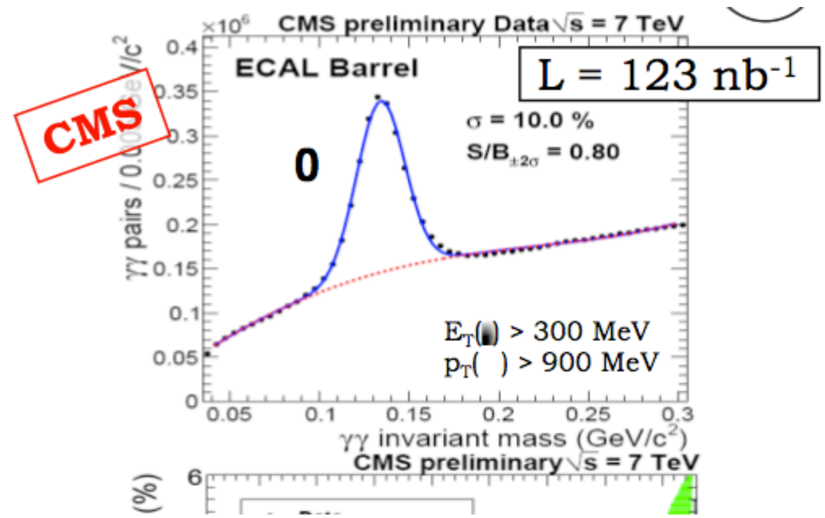
$$\frac{E}{E} \quad \frac{2.9\%}{\sqrt{E}} \oplus \frac{125\,\mathrm{MeV}}{\mathrm{E}} \oplus 0.3\%$$

- Inside solenoid coil

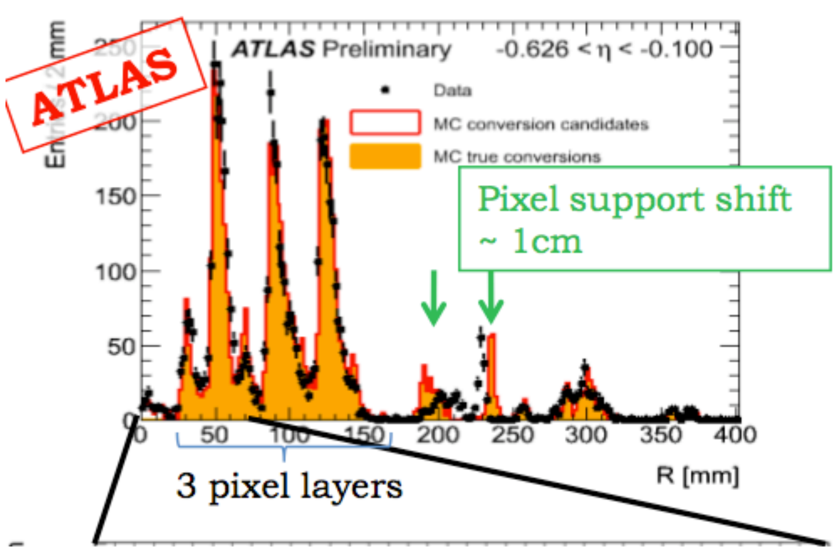
M. Aurousseau

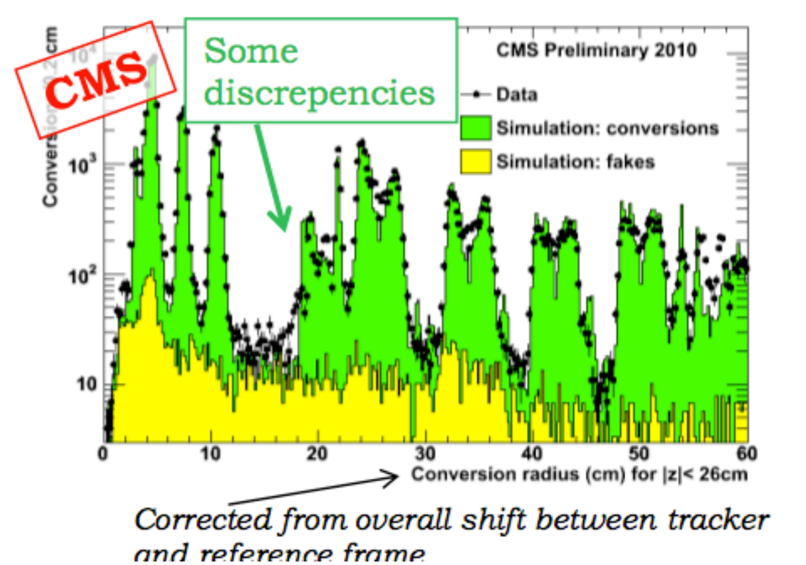
Using the π^0 As a Calibration Signal



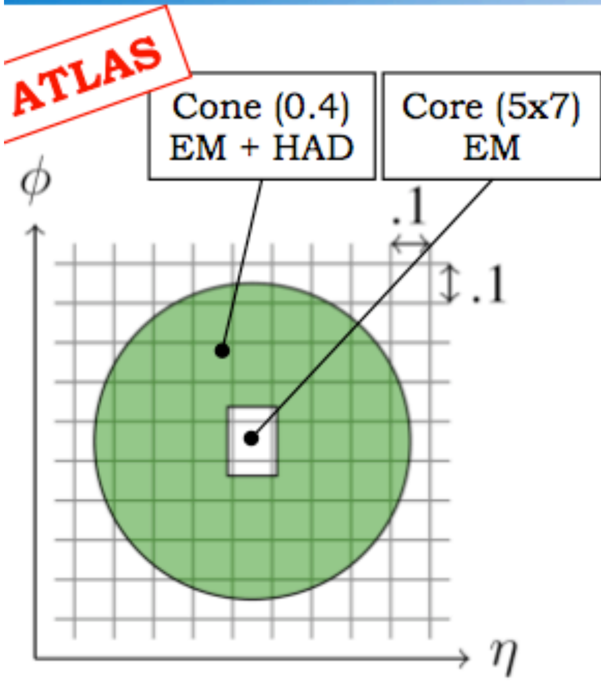


Using Conversions to Map Detector Material – Spectacular Moding in Very Early Running!





M. Aurousseau



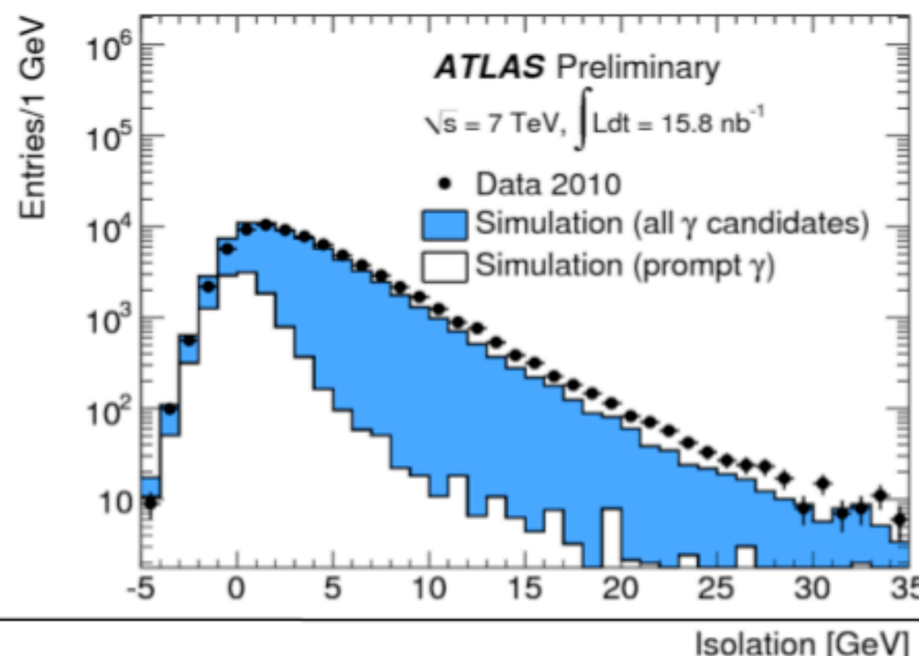
- **Energy in ring includes :**

→ Photon leakage out of the core
- Depends on photon pT
- Subtracted from the ring energy

→ Pile-up / Underlying Event effects
- Ambient energy density from low E jets
- Subtracted from the ring energy

→ Nearby hadronic activity → Isolation energy

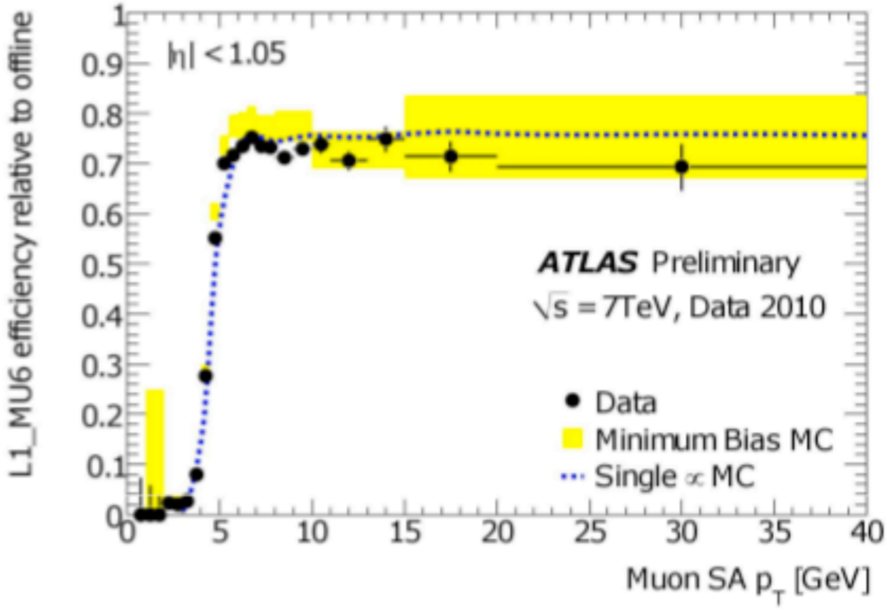
This definition of isolation is closer to theoretical parton-level isolation



Candidates already passing the loose ID cut

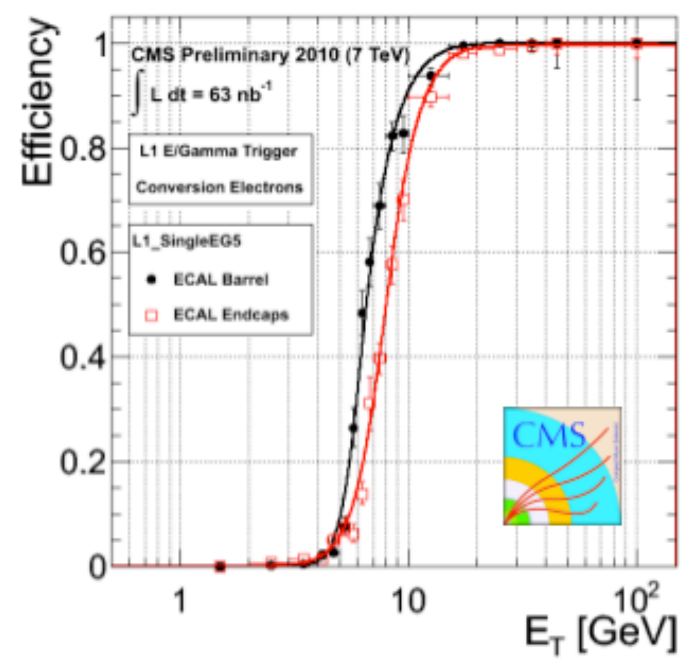
Triggering on Leptons

- Events are filtered online in 2 (CMS) or 3 (ATLAS) steps.

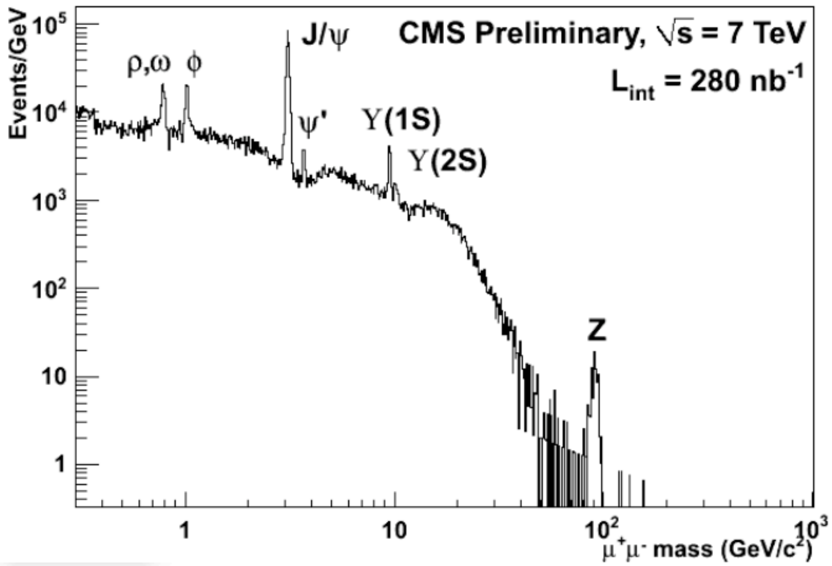


- **Level 1 Muon Trigger efficiency:**
  - Threshold at 6 GeV,
  - Eff. w.r.t "Stand Alone" offline Muon (reconstructed only with the Spectrometer)

- **Level 1 Electron Trigger efficiency:**
  - Threshold at 5 GeV,
  - Eff w.r.t ET of the ECAL super-cluster of the electron candidate
  - Measured on Minimum bias events with electrons from conversions.
  - Turnon gets sharper with isolated electrons from W&Z.



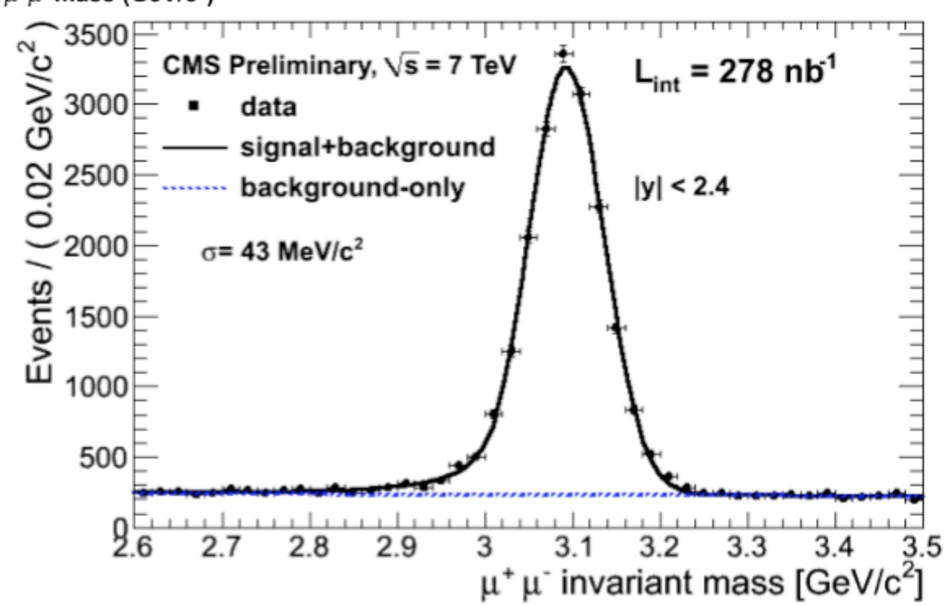
Lots of High s/b Samples to Calibrate Muon Efficiency and Energy Scale and Resolution



C. Ochando

Mean from data = 3.0927±0.0005 GeV

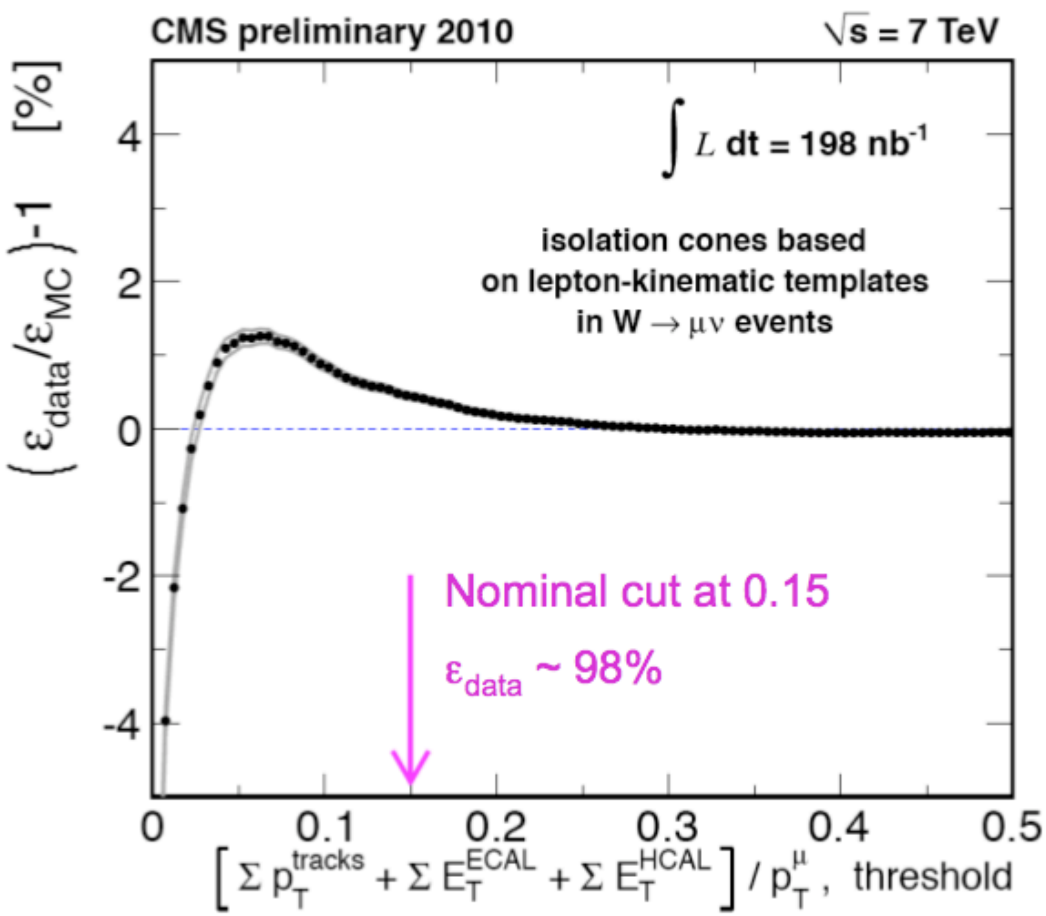
PDG mass = 3.0969±0.000011 GeV



R. Wilken

Muon Isolation

- Lepton-kinematic templates method used to calculate isolation efficiency

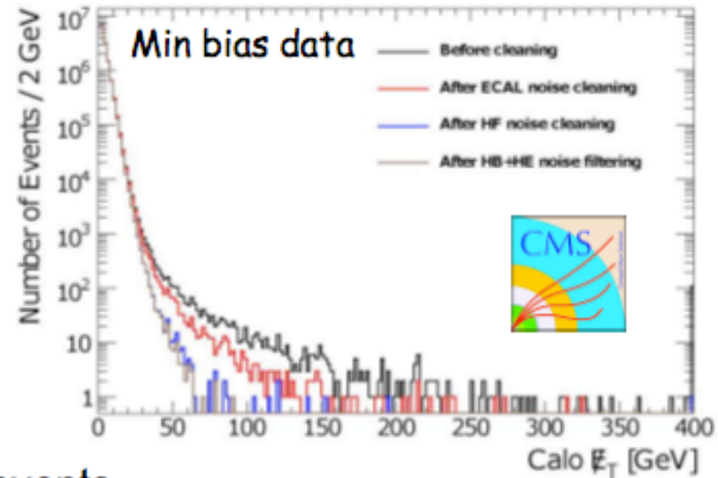


- Lepton-kinematic Templates use pre-defined directions from MC to estimate isolation in data
- Isolation calculated using 100 lepton-kinematic templates for each W->μν data event
- If template falls within 0.6 in eta and phi of muon then event thrown out

R. Wilken

Missing E_T

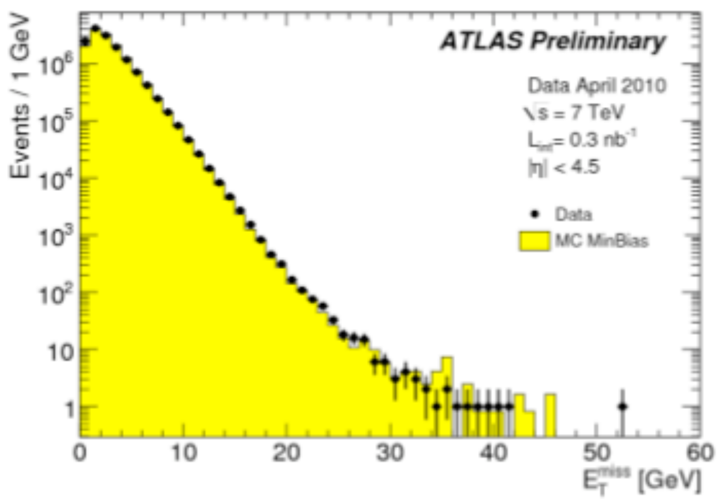
- Key variable for the W →ℓν analysis. (MET from escaping neutrinos).



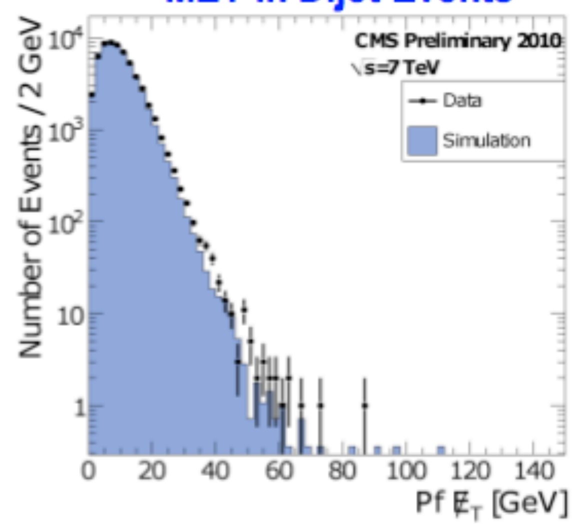
- Very sensitive to noise, pile-up, beam-halo background.
  => Need dedicated cleaning.

- Commissioned using Minimum Bias, Dijet (and W→ℓν) events.

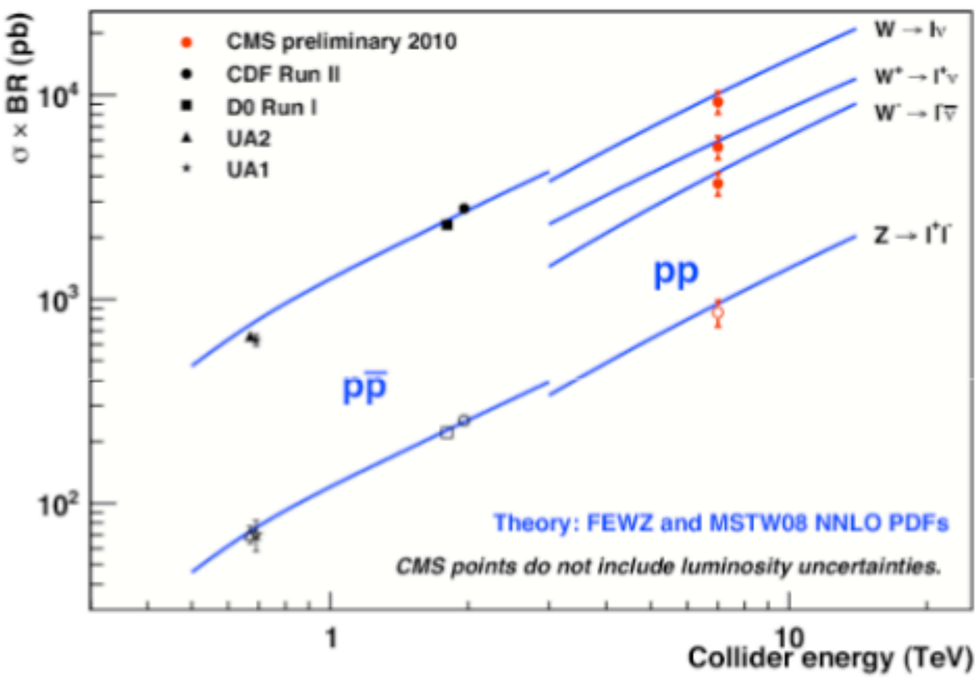
MET in Minimum Bias

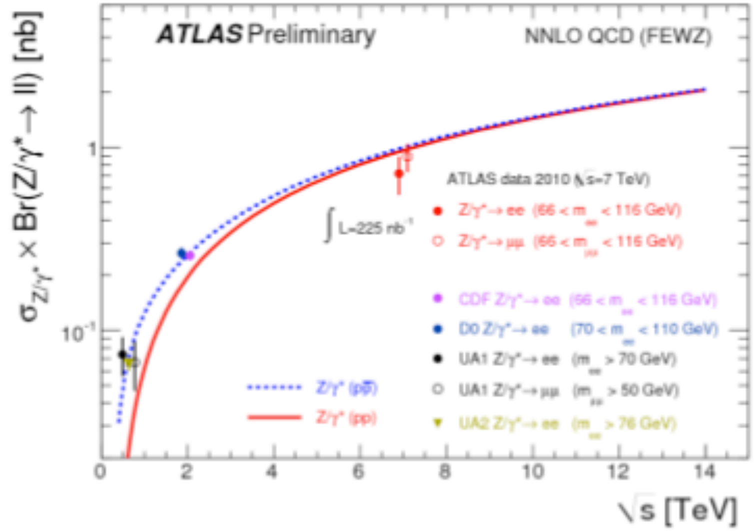


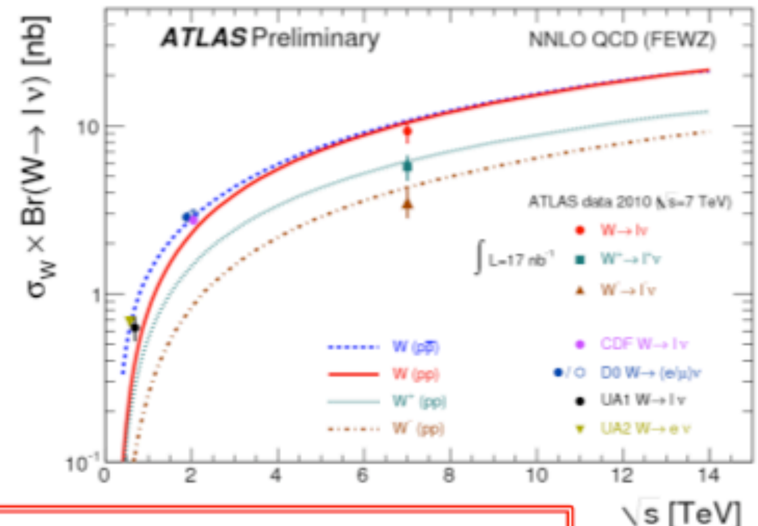
MET in Dijet Events



W&Z measurements summary (2)



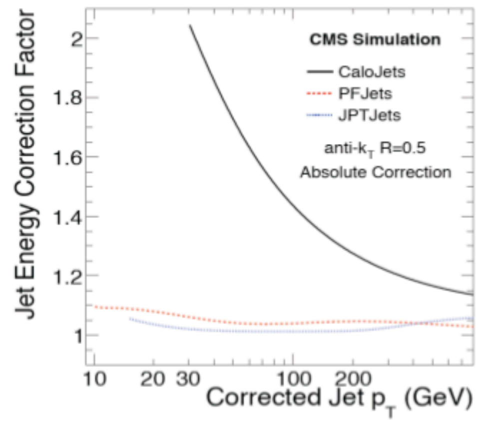




All the results are in agreement with the Standard Model expectations…
let's move further !

Jet Energy Scale and Resolution

Conservative uncertainties assigned for now



JES correction depends on jet type

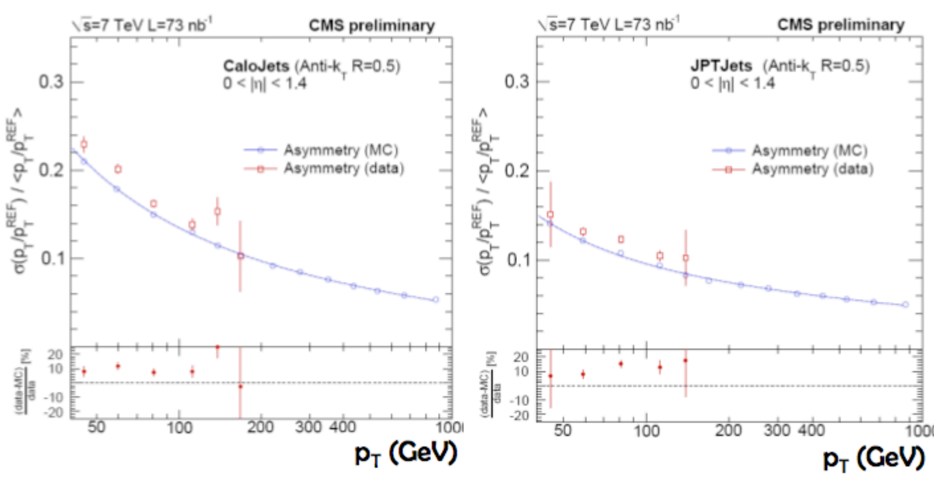
⇨ JES uncertainty depends on jet type

Conservative estimates:
- Calo jets: 10 %
- JPT and PF jets: 5%

} + 2 % · |η|

From single particle responses, eg. PF jets:
- EM scale: 1-2 %
- low pT: JES uncertainty of charged hadrons < 1 %
  JES uncertainty of neutral hadrons 3-5 %

- Jet Resolution Calibrated in Situ with dijet balancing – ATLAS and CMS

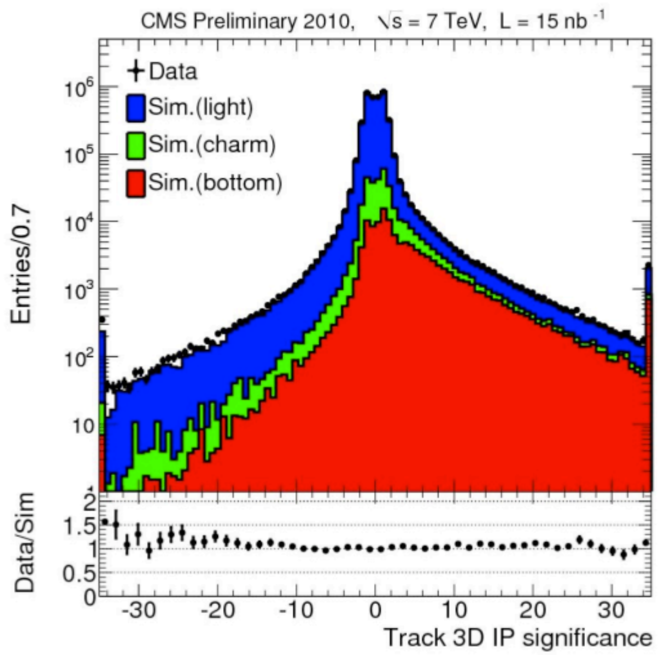


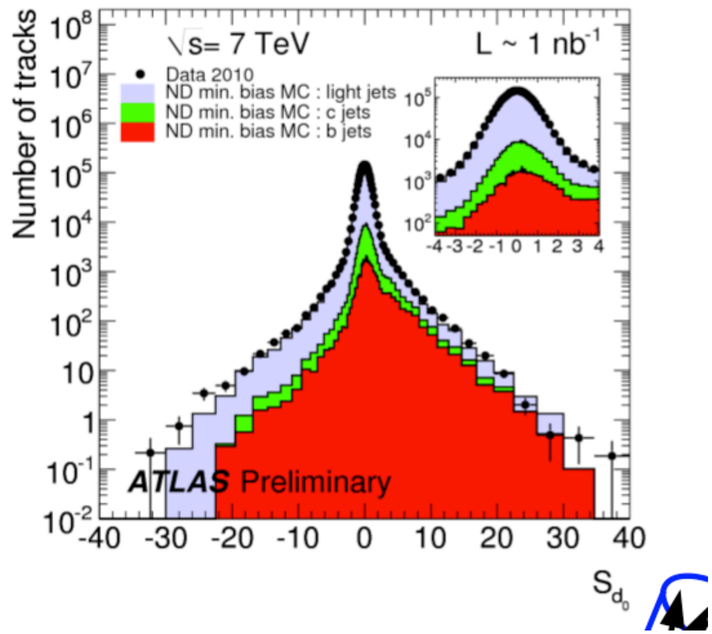
- Use of tracking info improves p_T resolution
- Jet resolution for PF jets very similar to JPT jets

← Uncertainties within 10 %

J. Schaarschmidt

LHC: B Tagging Performance



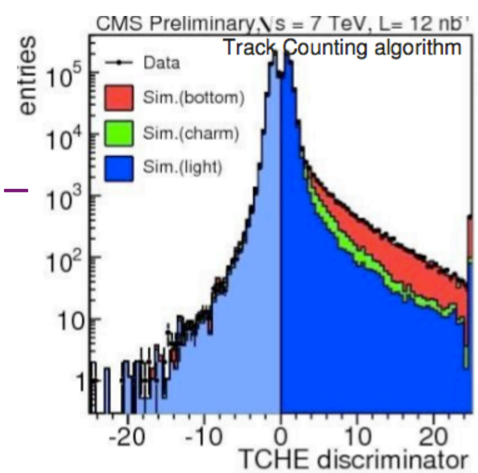


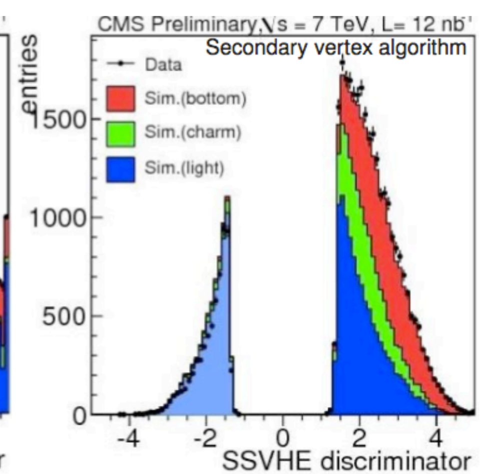
M. Bluj

Impact Parameter Significance – Normally it takes years to tune these up, and they look great!

Can fit the b fraction in tagged events using the P_T^{rel} distribution – calibrate the b-tag efficiency in the data

Mistags Estimated from negatively-tagged data



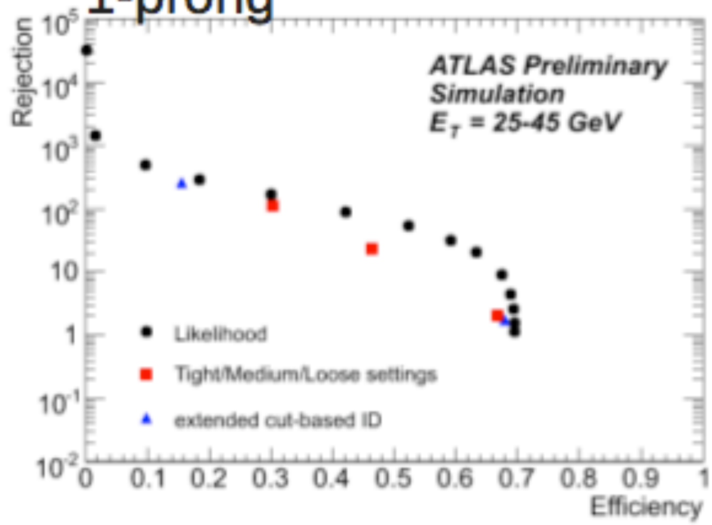


Mistag rate about 1% for 80 GeV jets

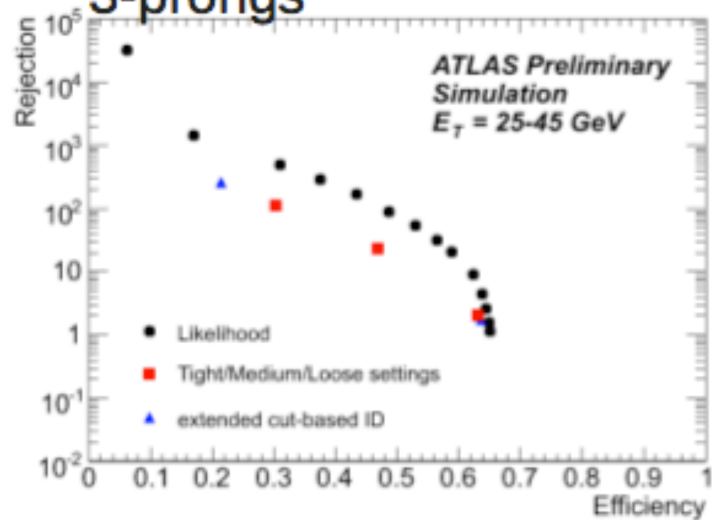
Tau-jet, expected performance

ATLAS

1-prong



3-prongs



Efficiency of tau identification vs quark/gluon jet rejection obtained with simulation ($Z \rightarrow \tau\tau$ and QCD di-jets samples)

- Optimized separately for 1- and 3-prongs in p_T bins

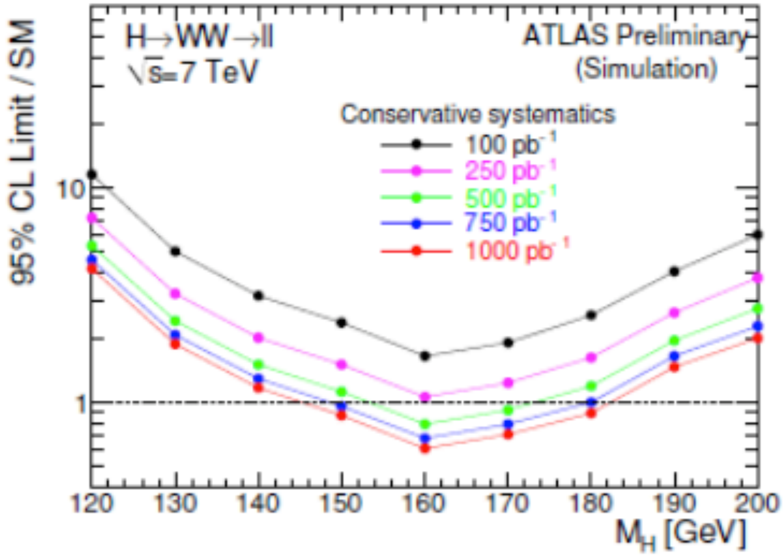
- **Expected performance** (medium working point, p_T=25-45 GeV):

  efficiency $\varepsilon_{sig} \approx$ 45-50% for rejection r ≈ 23 (“fake rate”: $\varepsilon_{bkg} \approx$ 4%)

  - Rejection: $r = 1/\varepsilon_{bkg} - 1$

Michał Bluj, Higgs Hunting 29-31 July 2010 17

Results H → WW* → 2l2ν



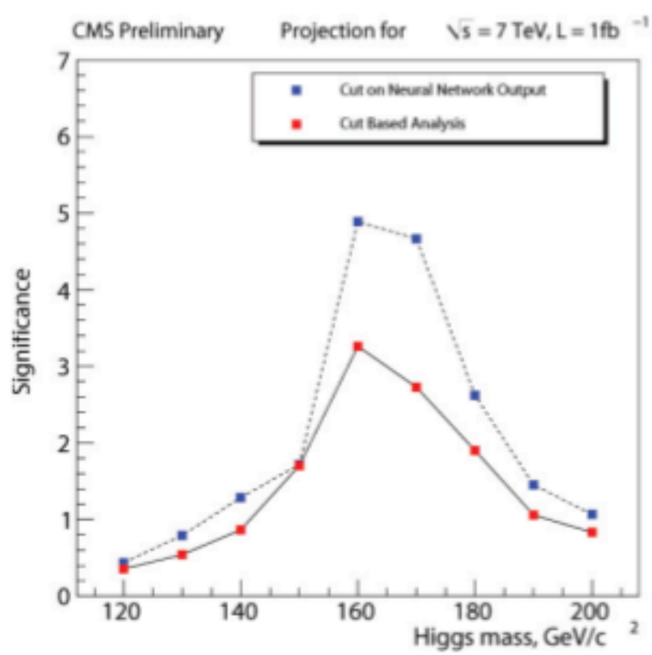
ATLAS (Ref. ATL-PHYS-PUB-2010-005 @10TeV)

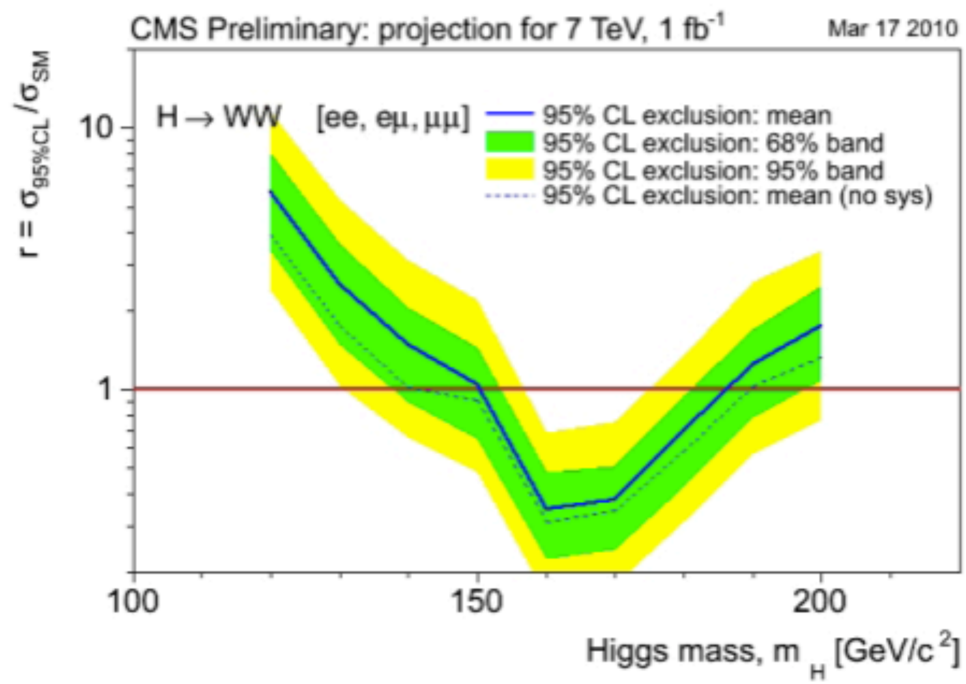
- A minimum of ∫Ldt = **250pb^{-1}** is required to be sensitive to the SM Higgs boson
- Exclusion 95%CL: **145<m_H<180 GeV/c^2**

CMS (Reference: CMS PAS HIG-08/006 @14TeV)

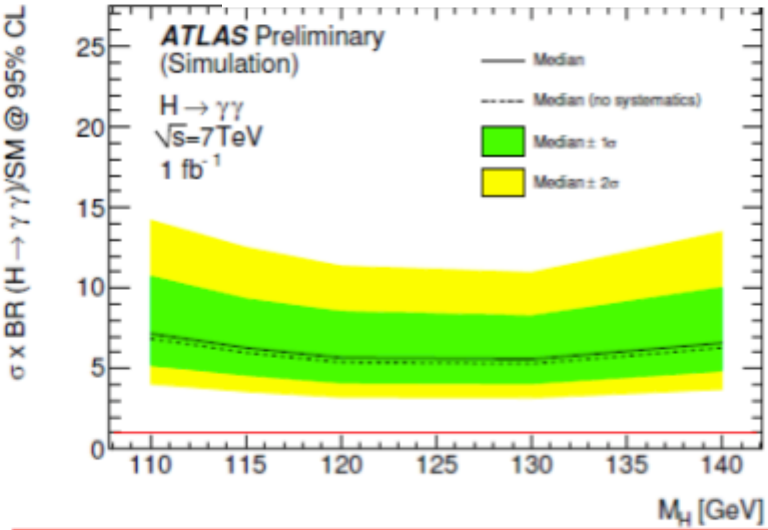
- Counting above a MVA-output cut
- Exclusion 95%CL: **150<m_H<185 GeV/c^2**

Discovery sensitivity (~5σ): **160<m_H<170GeV/c^2**





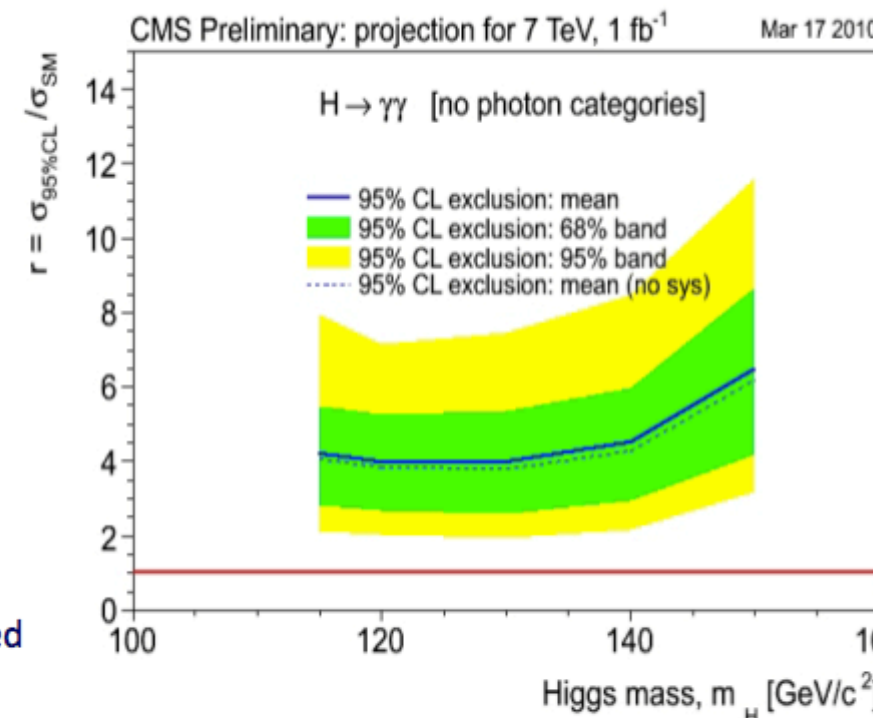
LHC Projections: $H \rightarrow \gamma\gamma$



ATLAS (Reference **CERN-OPEN-2008-020**@14 TeV)

- Profile likelihood method is used
- Expected exclusion is set using the signal-plus-background probability only

The SM Higgs cannot be excluded anywhere in the mass range



CMS (Reference PTDR @14 TeV)

- Counting in a mass window
- No photon categories.

No exclusion either.

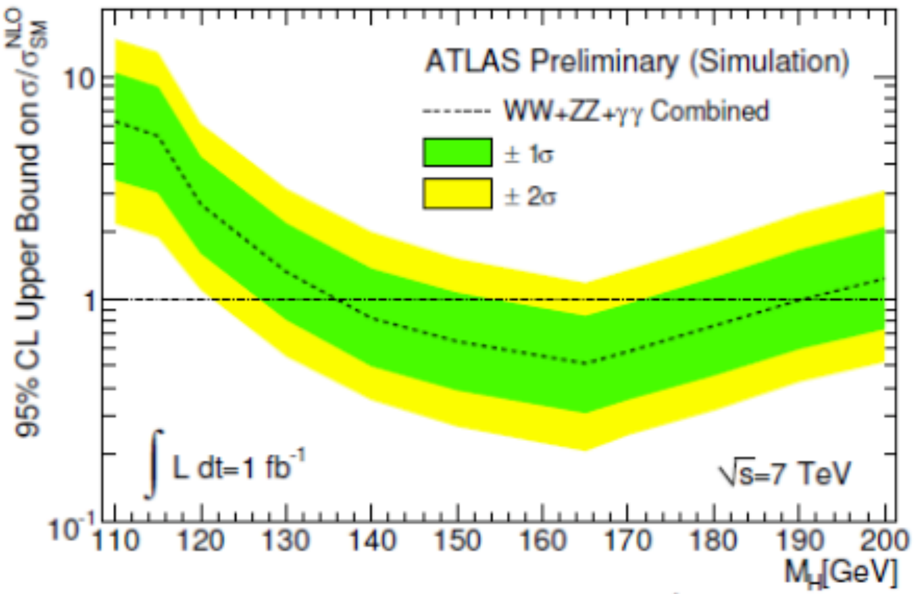
A fermio-phobic Higgs* with: **m_h<110 GeV** would be excluded, as for this mass range, the yield $\sigma(pp \rightarrow h_{fph}) \times BR(h_{fph} \rightarrow \gamma\gamma)$ is >4

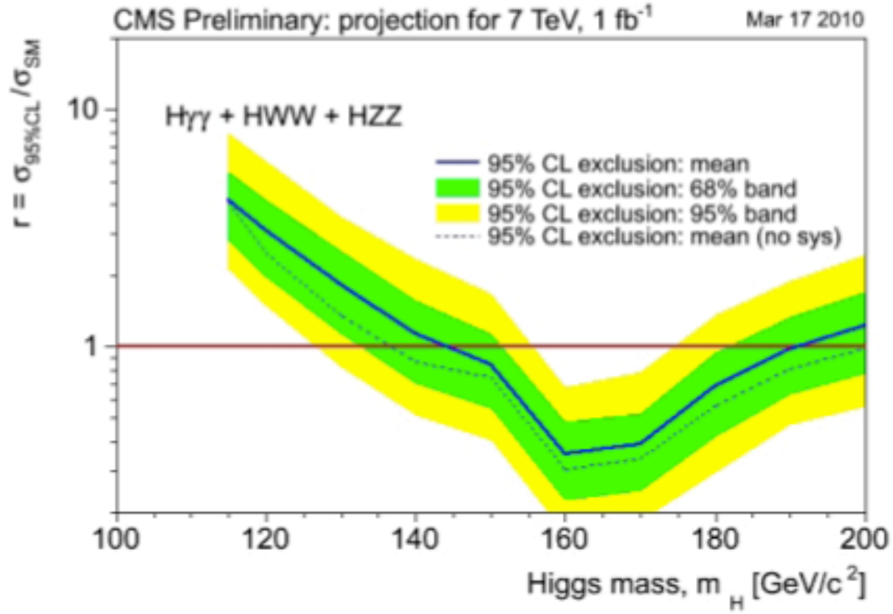
*The limit on the anomalous production is expected to be about 4 times $\sigma(pp \rightarrow H_{SM}) \times BR(H_{SM} \rightarrow \gamma\gamma)$.

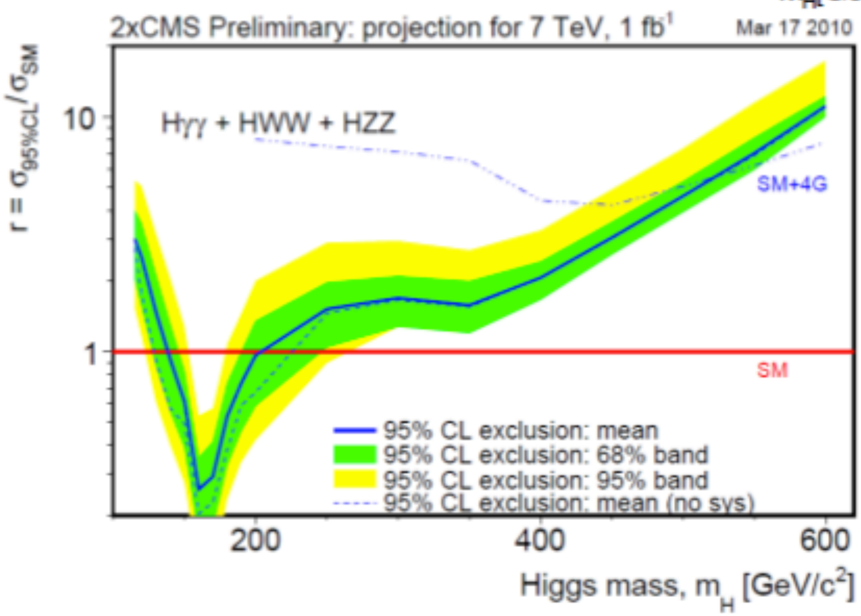
The projected exclusion reach is comparable to the current limits from LEP and Tevatron

30/07/2010 J. Fernandez 17

LHC SM Higgs Combination at 7 TeV







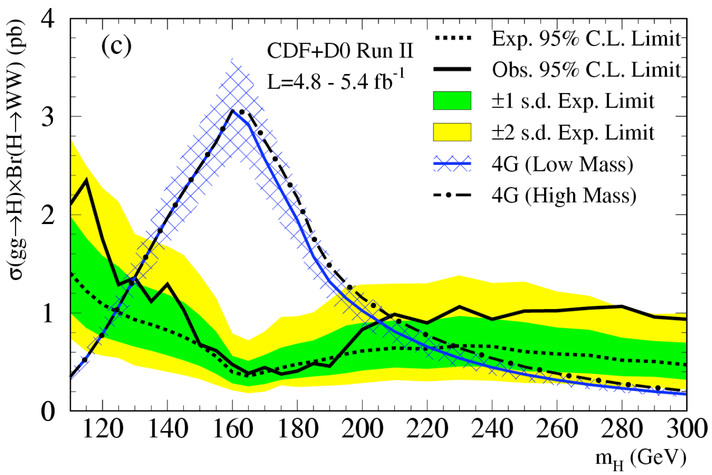
2xCMS :

Conservative and indicative projected exclusion limits assuming twice amount of data (ATLAS + CMS)

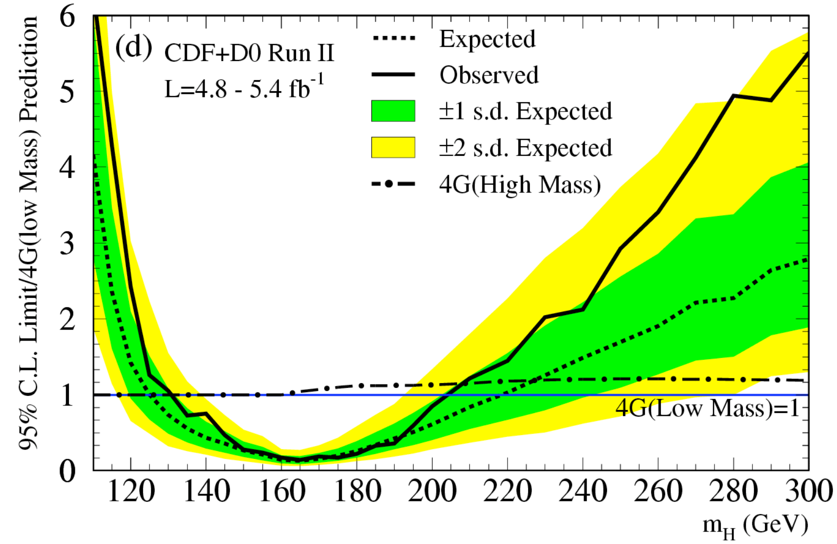
Exclusion: $140<m_H<200$ GeV/c^2

SM Higgs +4th fermion generation: $m_H<500$ GeV/c^2

Minimal BSM: Fourth Generation

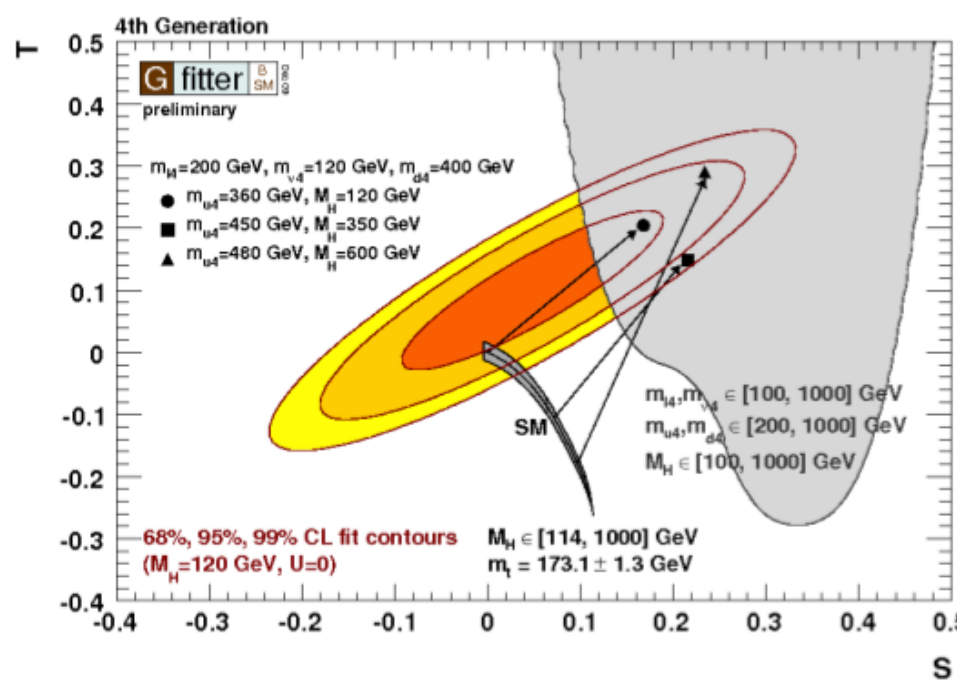


Theory prediction:
Anastasiou, Boughezal, and Furlan



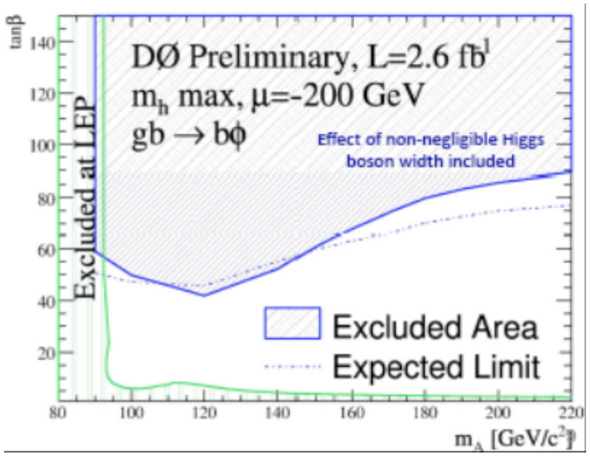
But: A fourth Generation can make m_H=400 GeV consistent with precision EW!

A. Hoecker

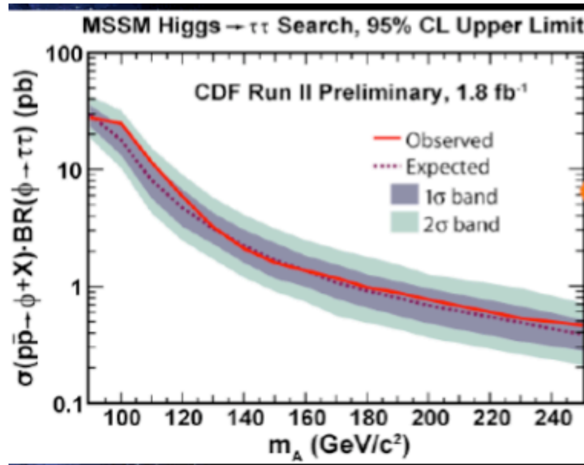


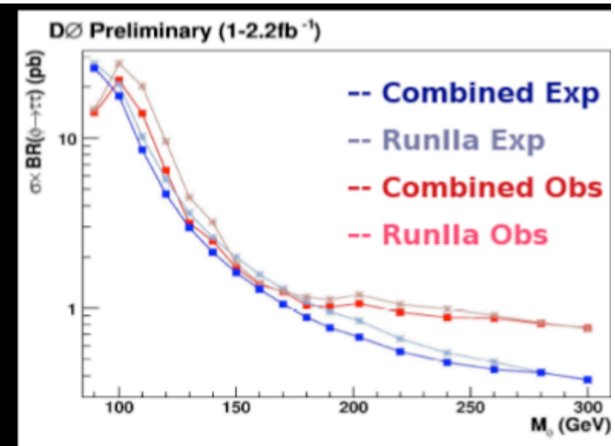
MSSM neutral Higgs: Tevatron

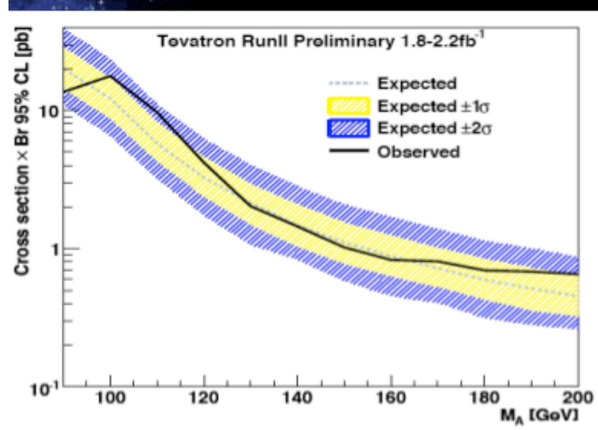
U.-K. Yang

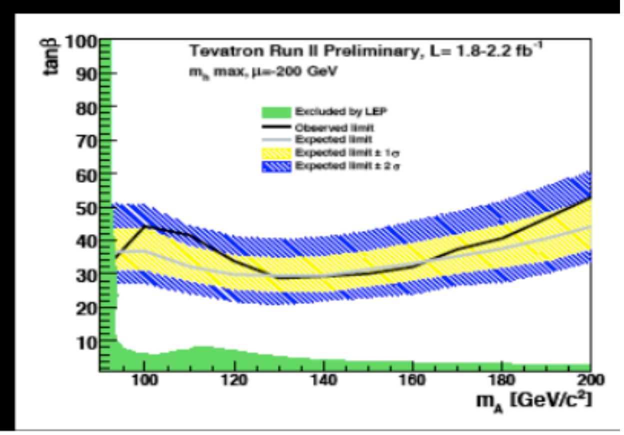


Inclusive H→ττ Search by CDF and D0, and combiantion

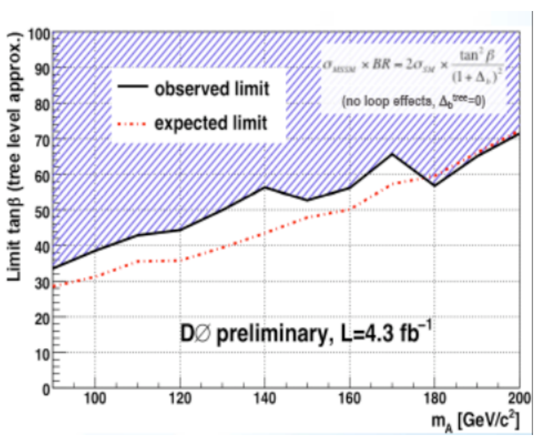








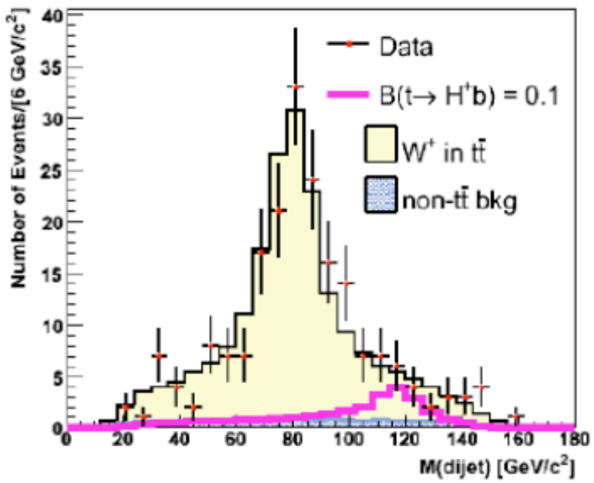
3b mode analyzed by CDF and D0 but not yet combined

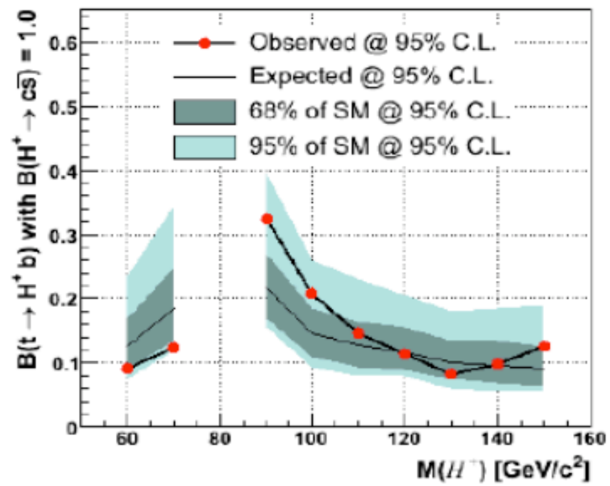


Also: bττ from D0 with a strong constraint

Light H± Search in Top Quark Decay

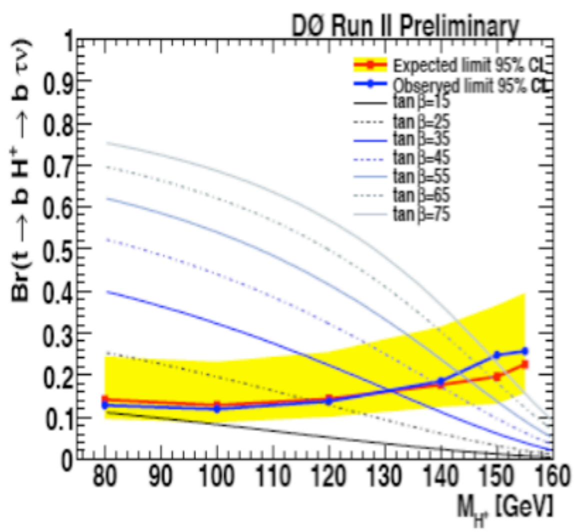
CDF: Search for a second bump in m_{jj} where it peaks at m_W in lepton+jets events

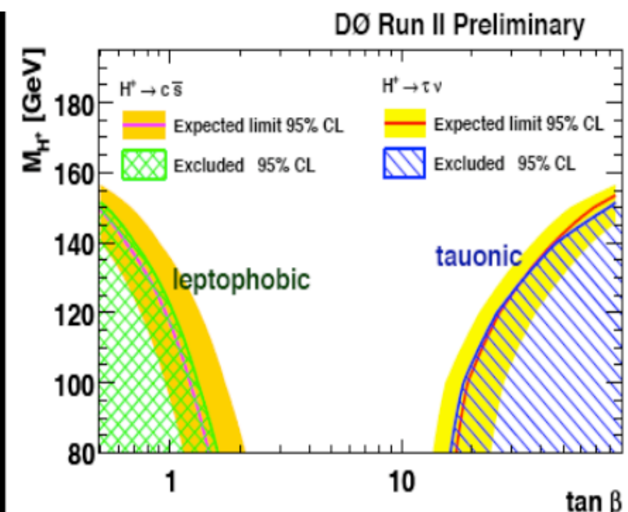




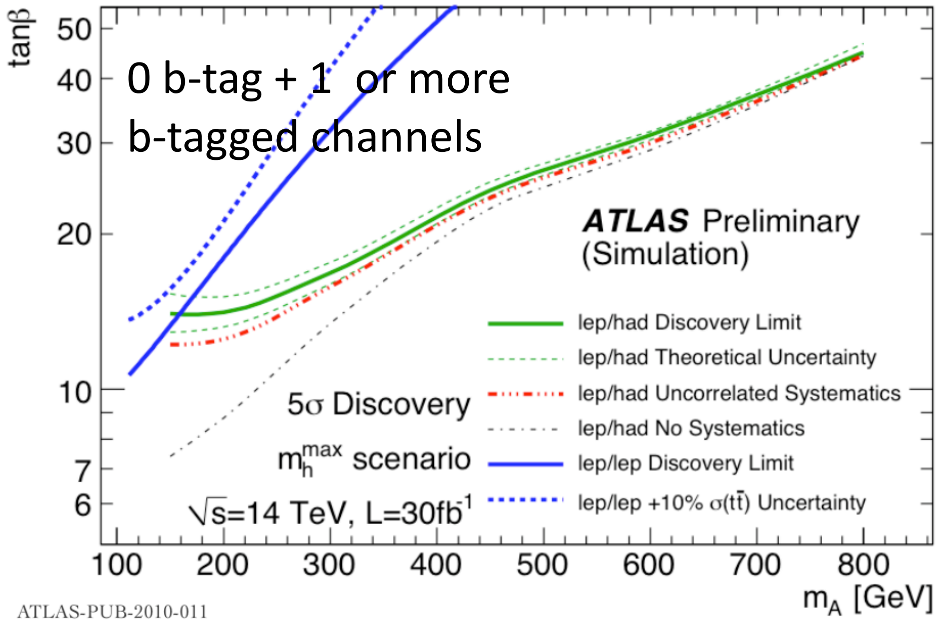
D0: Count events in dilepton, lepton+jets, tau+jets, lepton+tau & fit branching fractions

U.-K. Yang



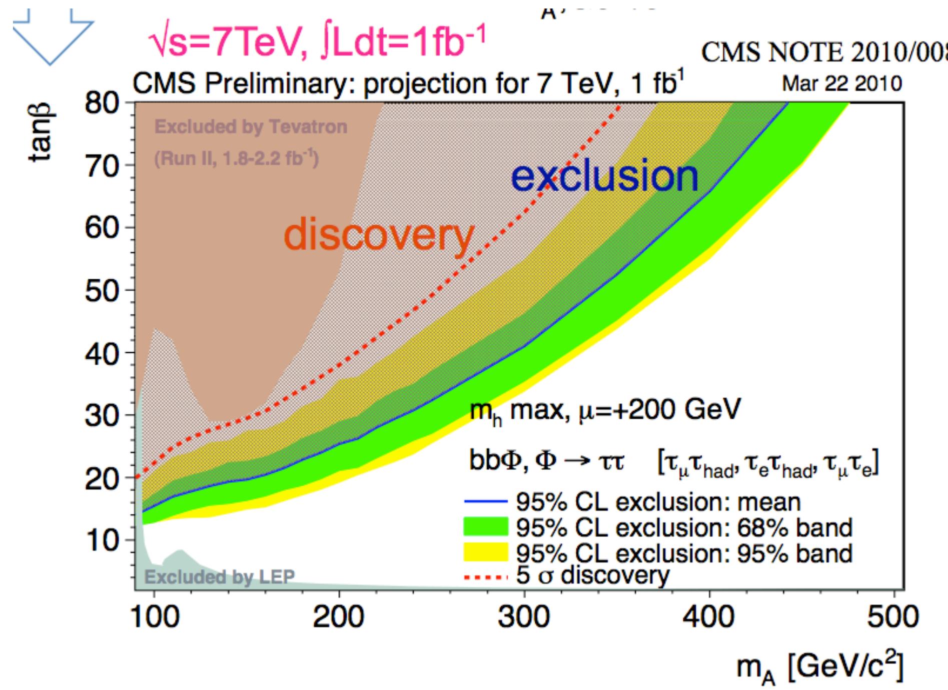


LHC H→ττ Sensitivity Projections



ATLAS-PUB-2010-011

K. Leney



R. Tanaka

Light Charged Higgs $M_{H\pm} < M_{top}$

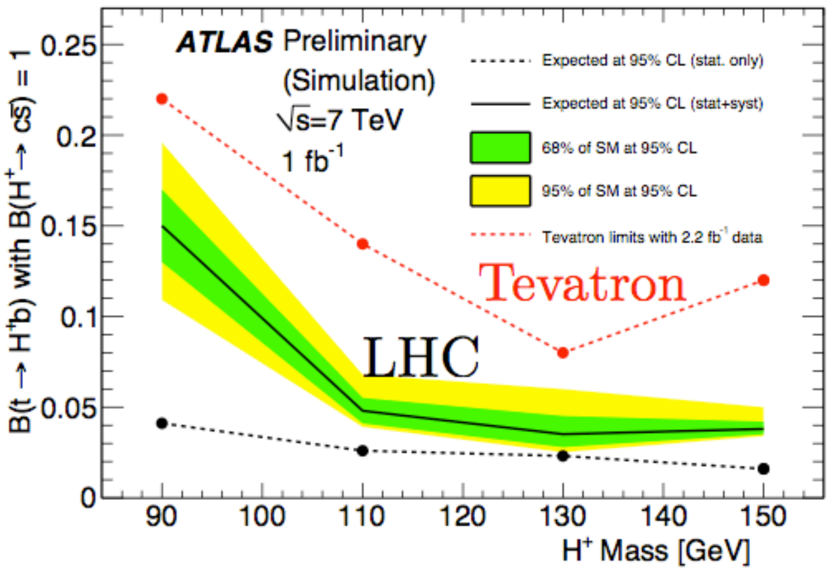
ATL-PHYS-PUB-2010-009

$\sqrt{s}$=7TeV, $\int Ldt$=1fb^{-1}

$$t\bar{t} \to (H^+b)(W^-b)$$

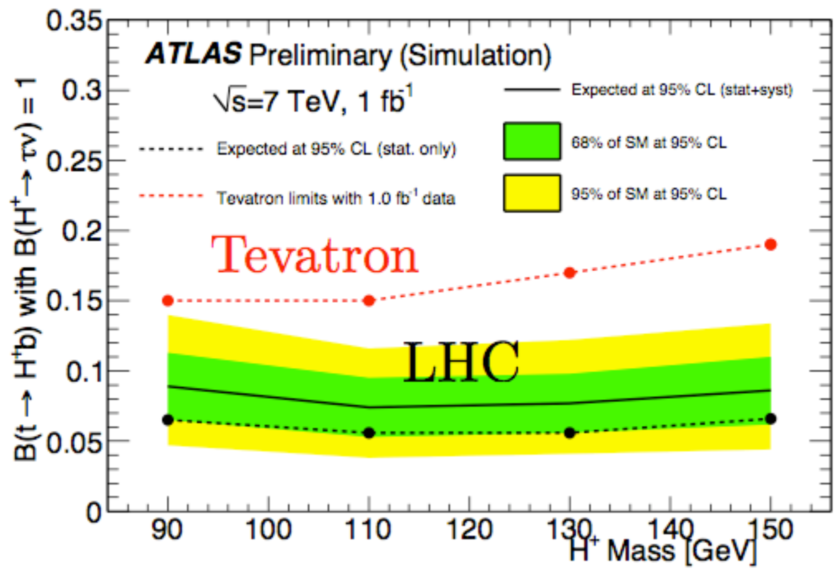
$$\mathrm{Semi-leptonic}\ t\bar{t},\ H^+ \to c\bar{s}$$

$$t\bar{t} \to (H^+b)(W^-\bar{b}) \to (c\bar{s}b)(\ell^-\nu\bar{b})$$



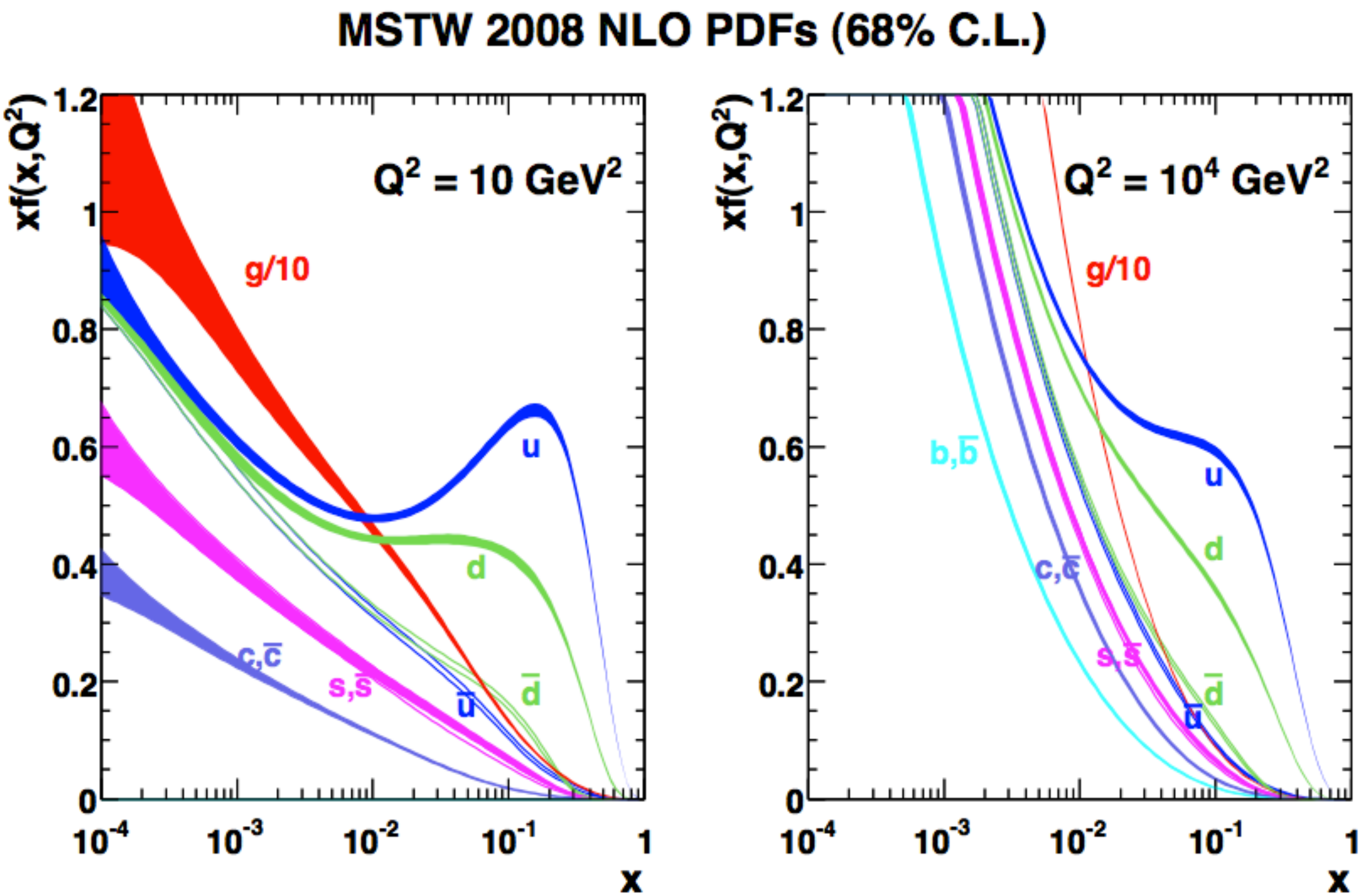
$$\mathrm{Di-lepton}\ t\bar{t},\ H^+ \to \tau^+\nu$$

$$t\bar{t} \to (H^+b)(W^-\bar{b}) \to (\tau^+b)(\ell^-\nu\bar{b}) \to (\ell^+\nu\nu\nu b)(\ell^-\nu\bar{b})$$



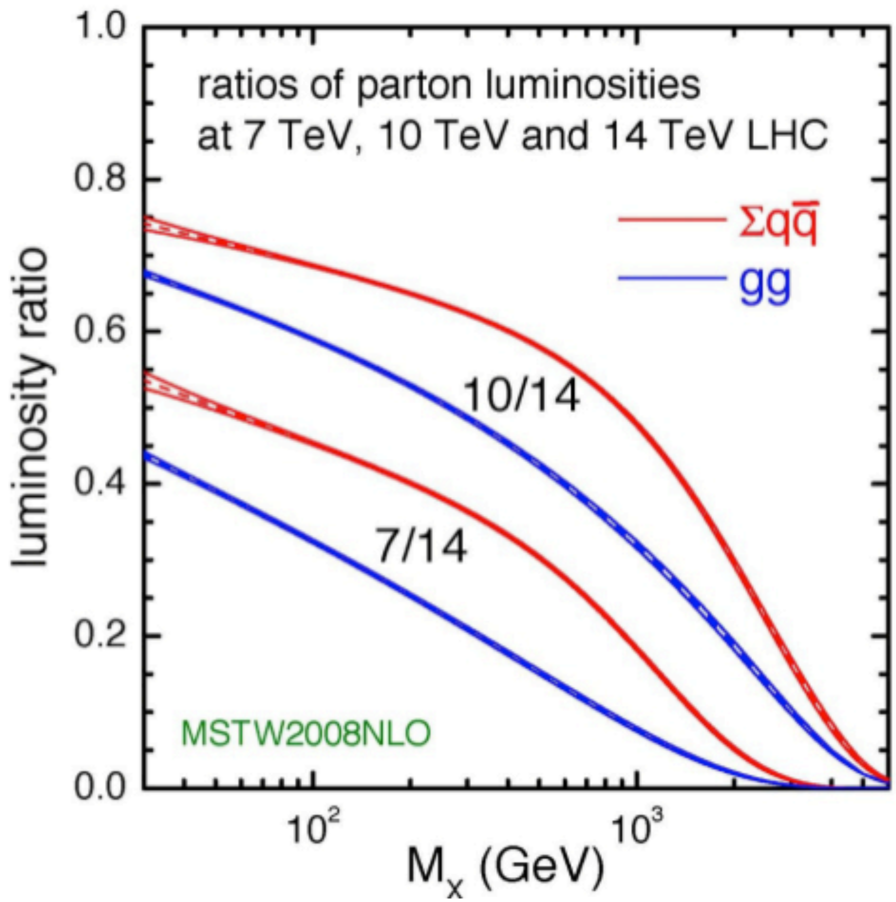
R. Tanaka

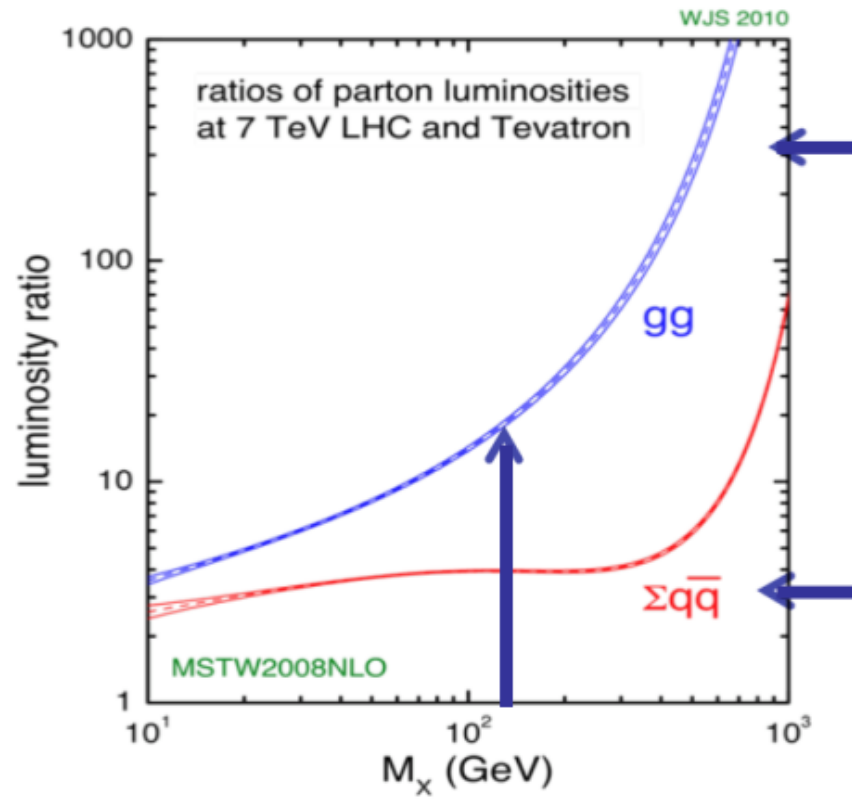
Parton Distribution Functions



R. Thorne

Parton Luminosities – Comparing 14 TeV LHC to 10 and 7 TeV LHC, and the Tevatron





J. Fernandez

Tevatron: 10 fb^{-1} analyzable/exp at 1.96 TeV by end 2011. Asking for three more years.
LHC: 1 fb^{-1} per exp by end 2011.
Much more data and energy later

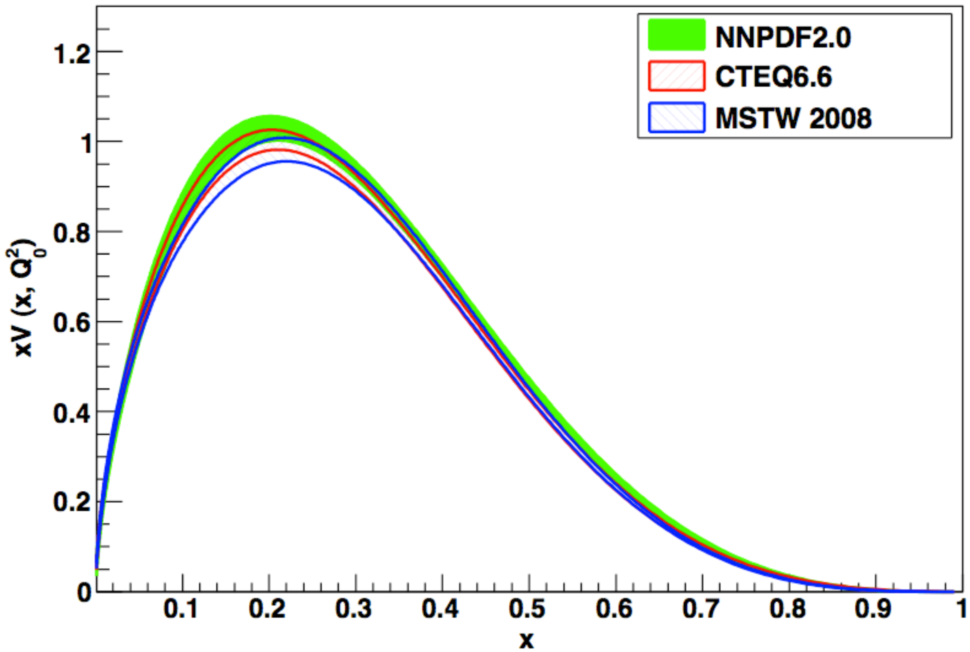
Different PDF sets

R. Thorne

- MSTW08 – fit all previous types of data. Most up-to-date Tevatron jet data. Not most recent HERA combination of data. PDFs at LO, NLO and NNLO.
- CTEQ6.6 – very similar. Not quite as up-to-date on Tevatron data. PDFs at NLO. New – CT10 include HERA combination and more Tevatron data. Little changes.
- NNPDF2.0 – include all except HERA jet data (not strong constraint) and heavy flavour structure functions. Include HERA combined data. PDFs at NLO.
- HERAPDF1.0 – based entirely on HERA inclusive structure functions, neutral and charged current. Use combined data. PDFs at LO, NLO and now NNLO.
- ABKM09 – fit to DIS and fixed target Drell-Yan data. PDFs at NLO and NNLO.
- GJR08 – fit to DIS, fixed target Drell-Yan and Tevatron jet data. PDFs at NLO and NNLO.

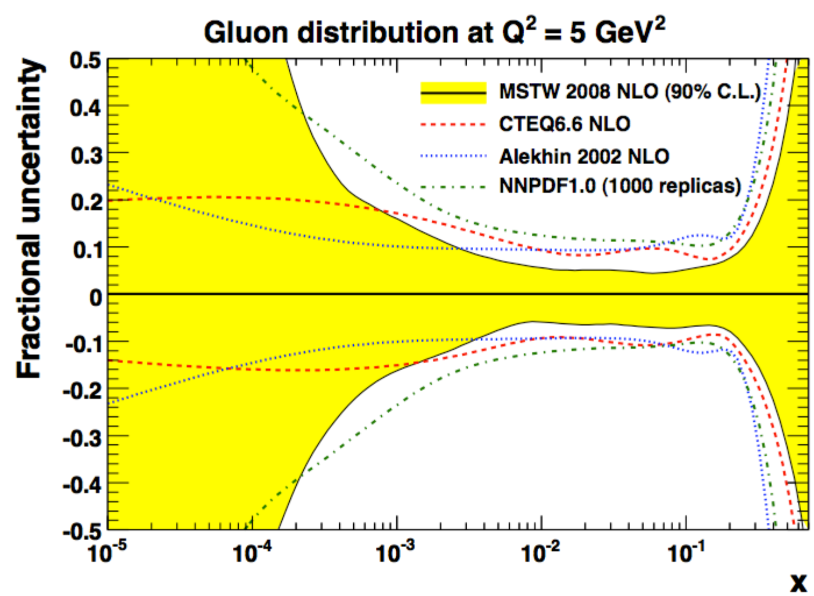
Use of HERA combined data instead of original data slight increase in quarks at low x (depending on procedure).

Valence Quark PDFs and Uncertainties Largely Under Control



Uncertainties on, e.g. valence quarks not notably different to other groups at al

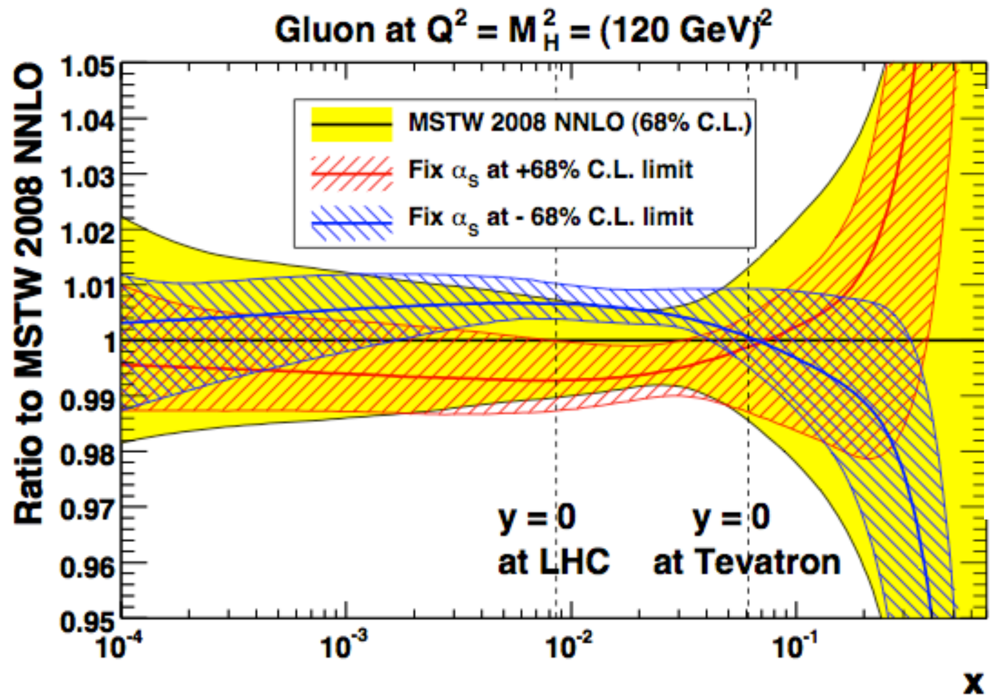
But variations in the predicitons of small-x gluons

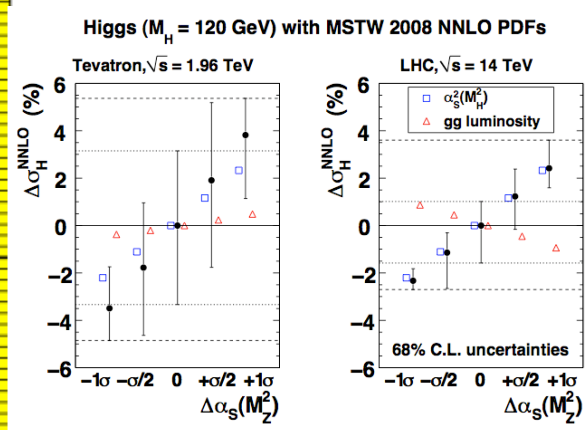


PDF correlation with α_S.

Can also look at PDF changes and uncertainties at different $\alpha_S(M_Z^2)$. Latter usually only for one fixed $\alpha_S(M_Z^2)$. Can be determined from fit, e.g. $\alpha_S(M_Z^2) = 0.1202^{+0.0012}_{-0.0015}$ at NLO and $\alpha_S(M_Z^2) = 0.1171^{+0.0014}_{-0.0014}$ at NNLO from MSTW.

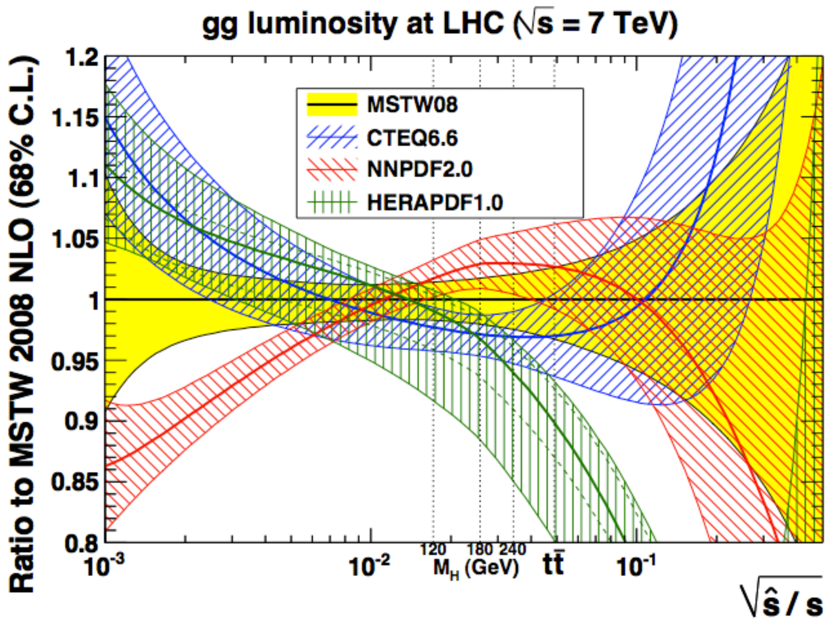
PDF uncertainties reduced since quality of fit already worse than best fit.

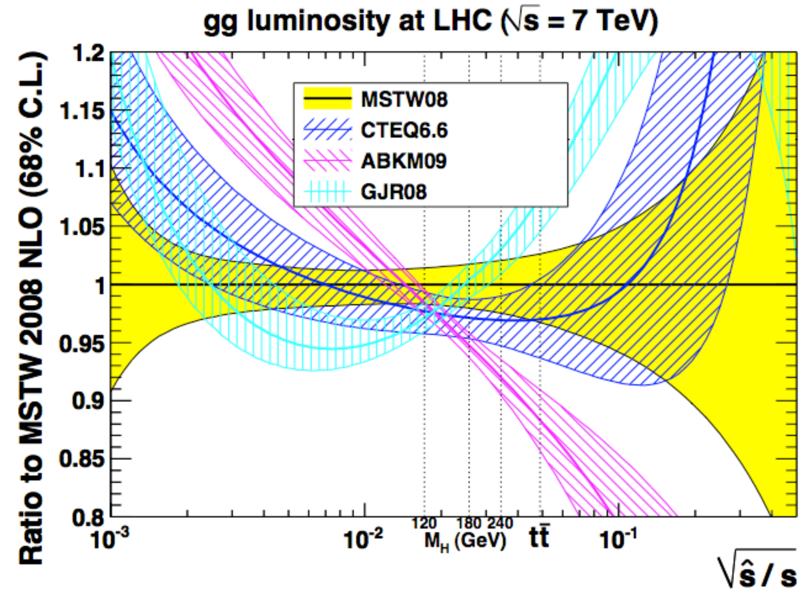


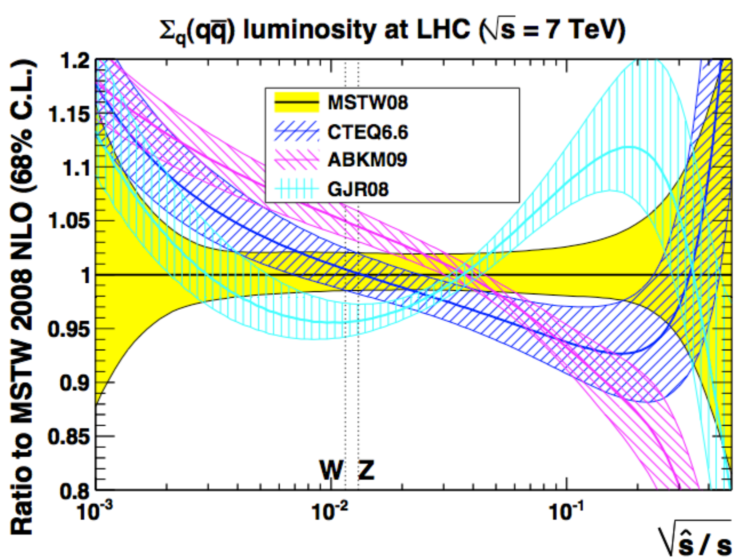


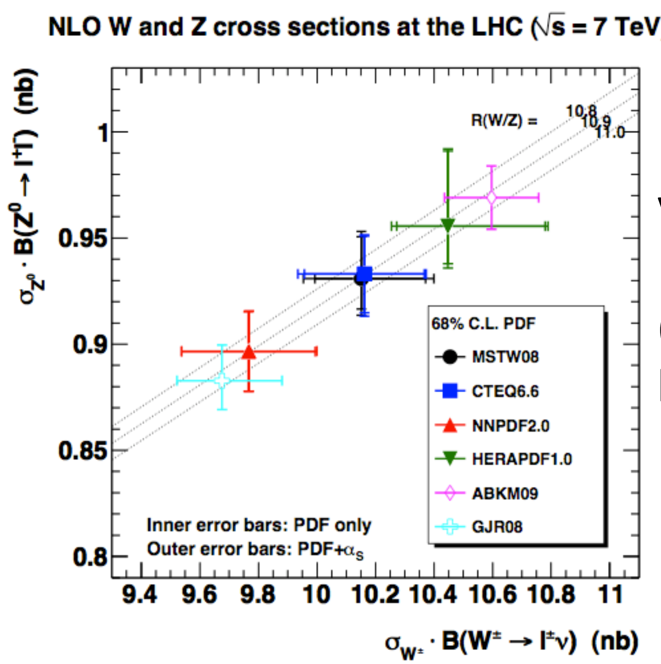
Expected gluon–$\alpha_S(M_Z^2)$ small–x anti-correlation $\rightarrow$ high-x correlation from sum rule.

Variations in Predictions for Different PDF Sets



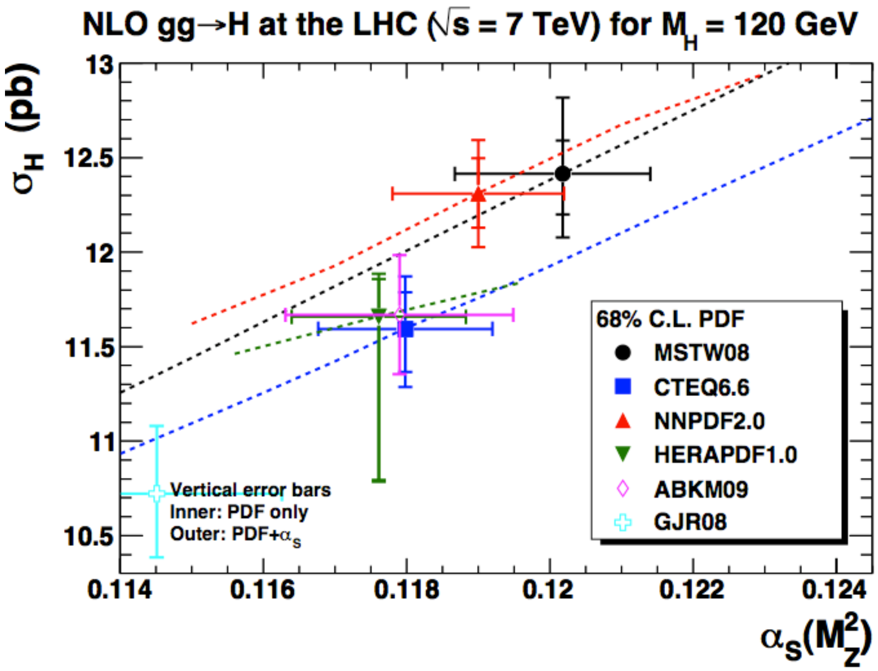




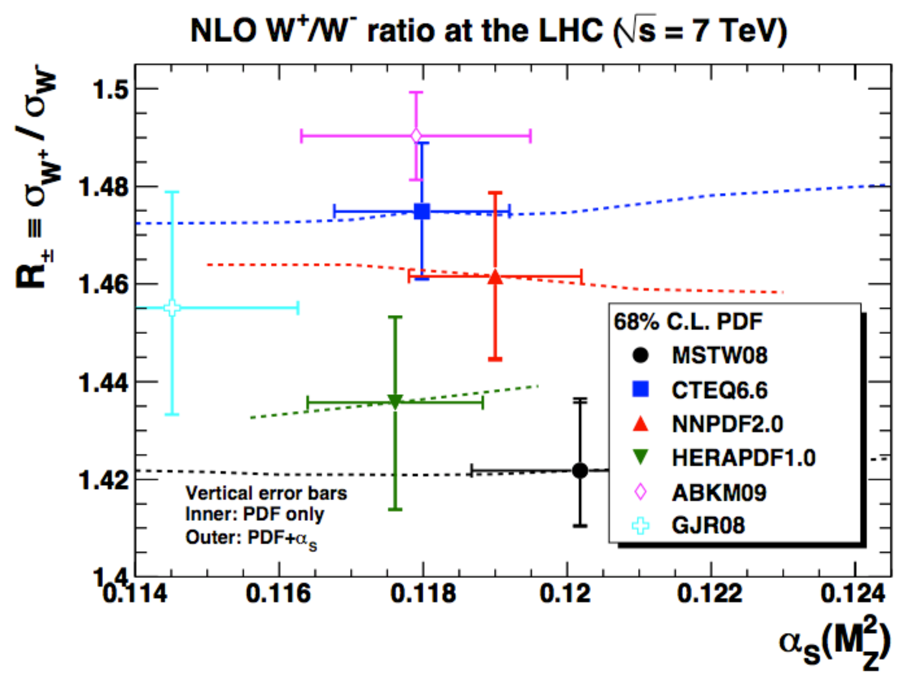


Very Measurable! (but need luminosity!)

Variations in Predictions for Different PDF Sets



gg→H Production cross section depends largely on the α_s value associated with the PDF set



But the Ratio of W^+ to W^- Doesn't seem to depend on α_s!

PDF's are an extrapolation from lower energies to the LHC.
Surprises can still come from nucleon structure!

Summary

- Many thanks to the Organizers! Louis, Gregorio, Abdelhak, Yves, Gautier, and the whole committee

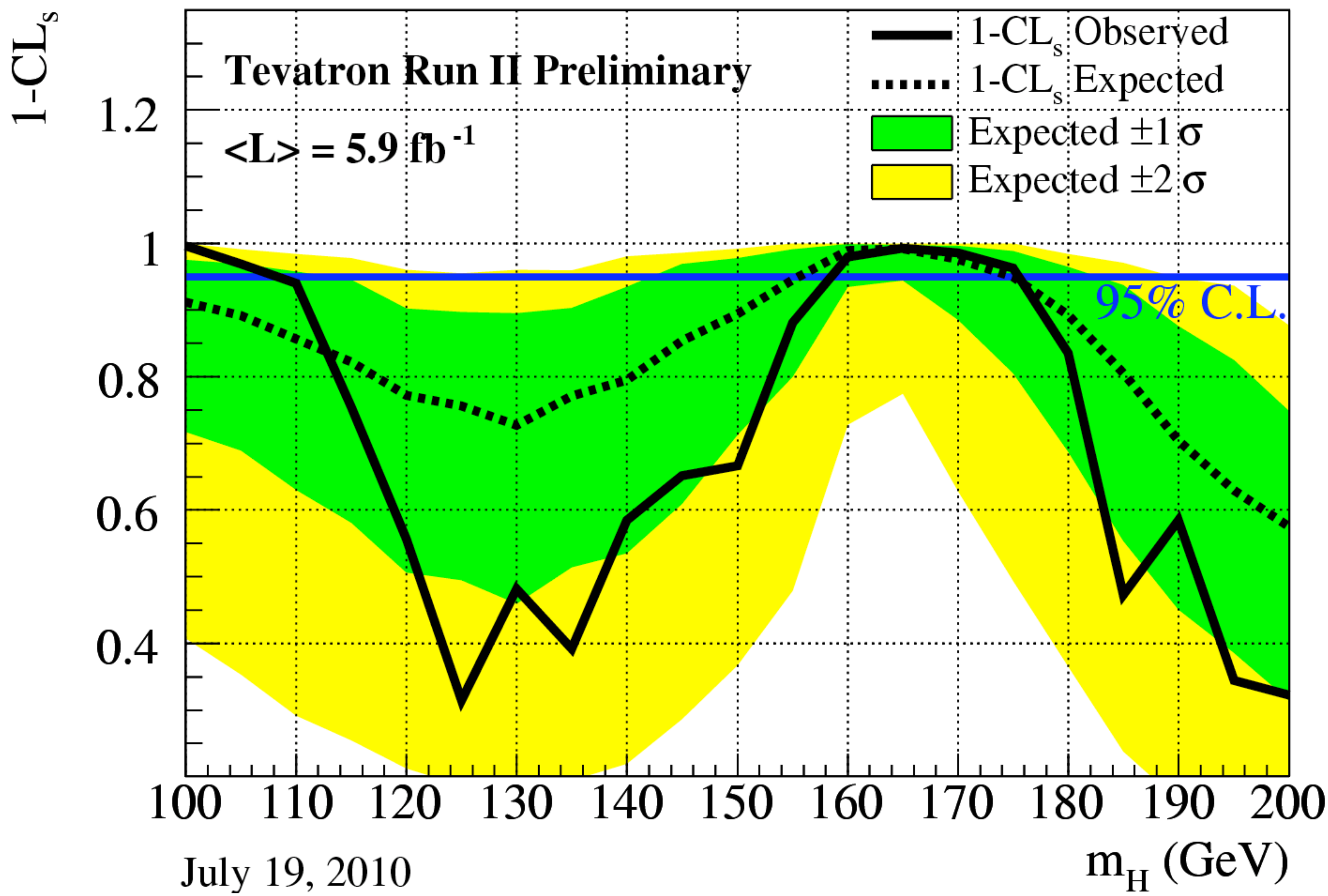
- Many thanks for the opportunity to get experimentalists and theorists together! We are making progress much more efficiently face to face

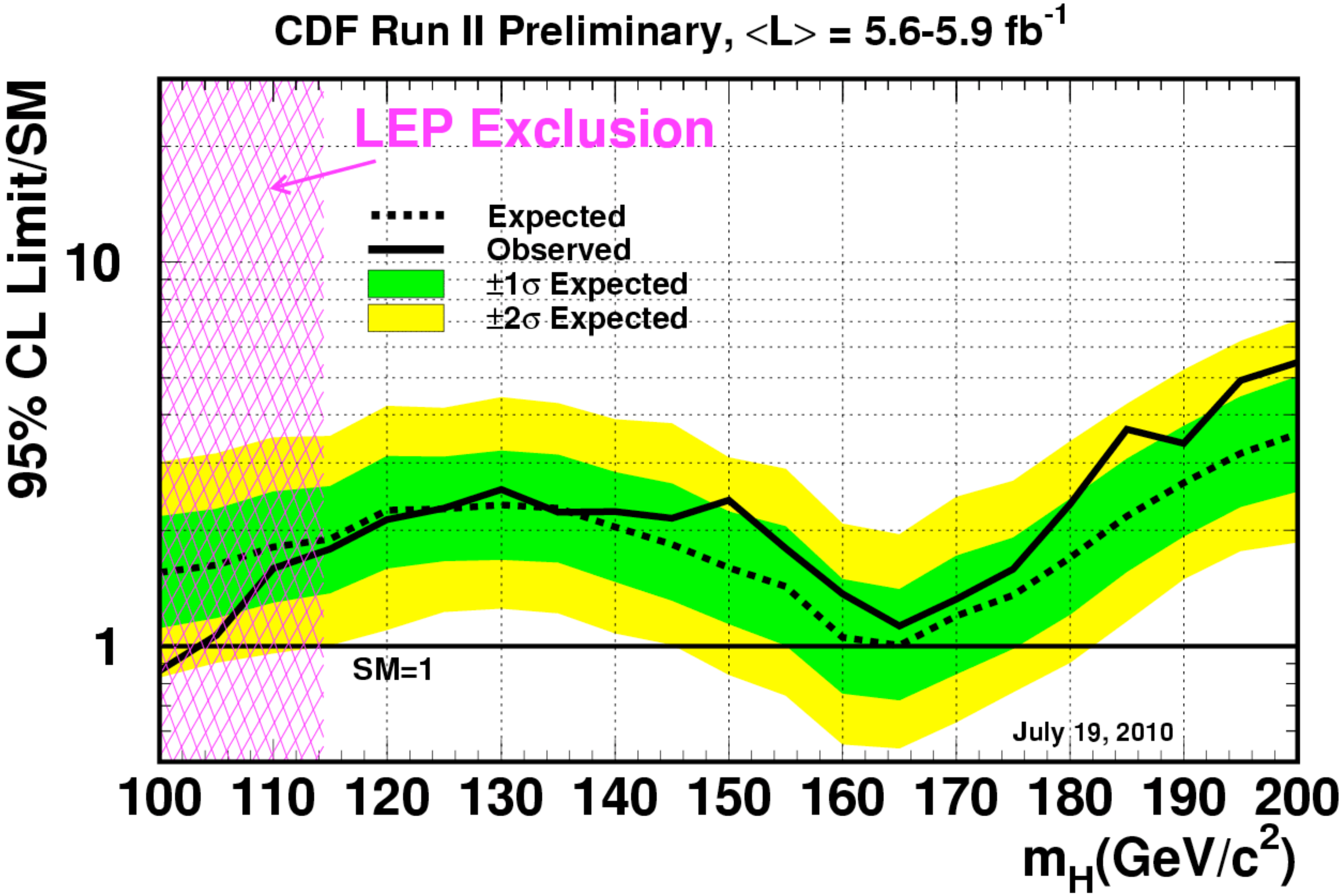
- The young scientist forum was fantastic! Keep up the good work!

- It is a great time to hunt for the Higgs boson.
    - The Tevatron is performing very very well and is testing for the presence of the SM Higgs boson
    - The LHC Detectors are working very very well on the first data
    - The LHC is running at 3.5 times the Tevatron energy and will accumulate soon enough data to test for the SM Higgs boson and hopefully find something new.
- The Tevatron and the LHC will be able to answer different questions on the near timescale. 165? Same question. Low mass? Very high mass?

So let's go find the Higgs Boson(s) already!

Backup Material


1-CL_s
Tevatron Run II Preliminary
<L> = 5.9 fb -1
1-CL_s Observed
1-CL_s Expected
Expected ±1 σ
Expected ±2 σ
95% C.L.
1.2
1
0.8
0.6
0.4
100 110 120 130 140 150 160 170 180 190 200
July 19, 2010
m_H (GeV)

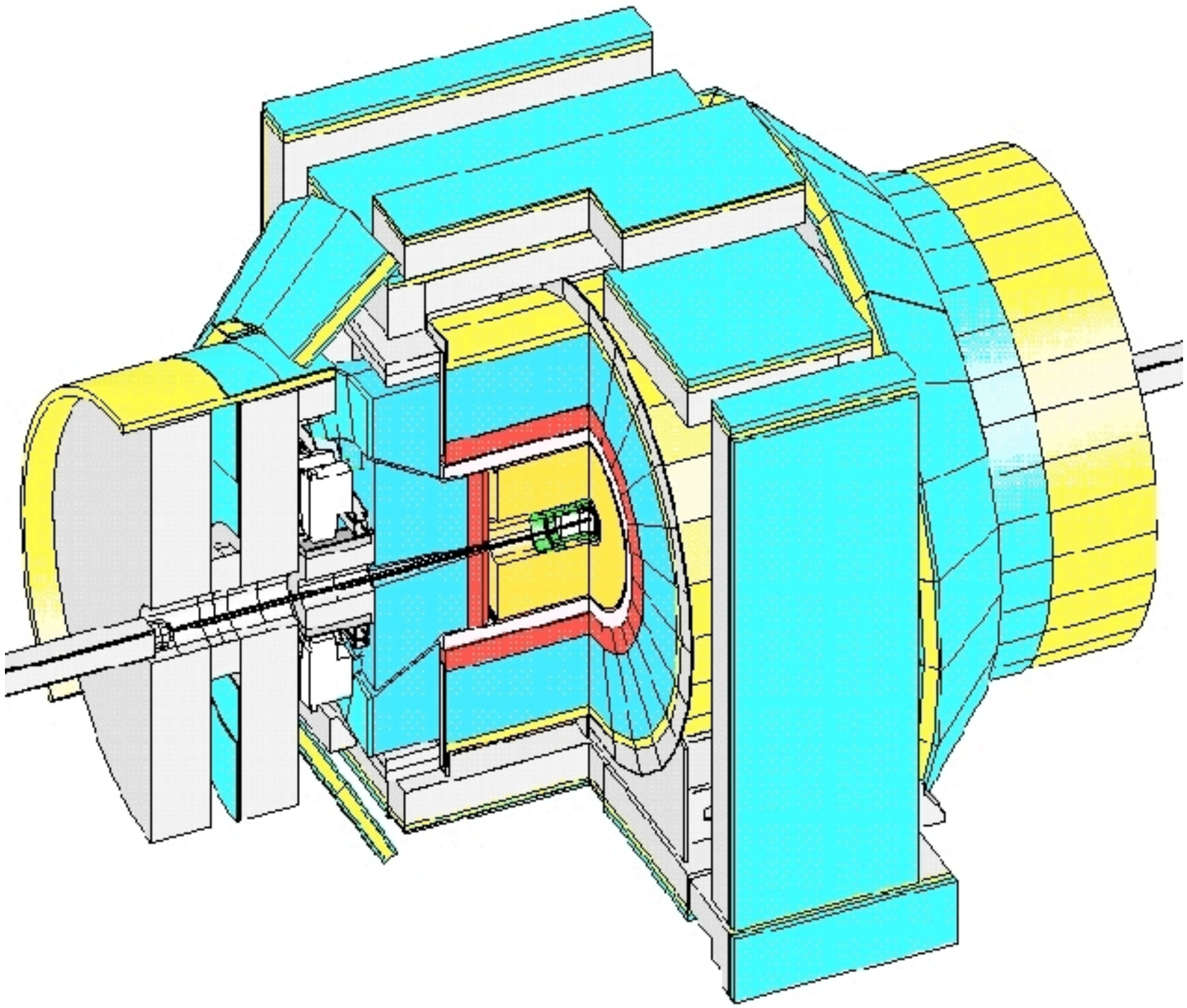


CDF Run II Preliminary, <L> = 5.6-5.9 fb^{-1}
LEP Exclusion
Expected
Observed
±1σ Expected
±2σ Expected
SM=1
July 19, 2010
95% CL Limit/SM
10
1
100
110
120
130
140
150
160
170
180
190
200
$m_H(GeV/c^2)$

TABLE I: The production cross sections and decay branching fractions for the SM Higgs boson assumed for the combination.

m_H (GeV/c^2)	$\sigma_{gg\to H}$ (fb)	σ_{WH} (fb)	σ_{ZH} (fb)	σ_{VBF} (fb)	$\sigma_{t\bar{t}H}$ (fb)	$B(H\to b\bar{b})$ (%)	$B(H\to c\bar{c})$ (%)	$B(H\to\tau^+\tau^-)$ (%)	$B(H\to W^+W^-)$ (%)	$B(H\to ZZ)$ (%)	$B(H\to\gamma\gamma)$ (%)
100	1861	291.9	169.8	99.5	8.000	80.33	3.542	7.920	1.052	0.1071	0.1505
105	1618	248.4	145.9	93.3	7.062	78.57	3.463	7.821	2.307	0.2035	0.1689
110	1413	212.0	125.7	87.1	6.233	75.90	3.343	7.622	4.585	0.4160	0.1870
115	1240	181.9	108.9	79.07	5.502	71.95	3.169	7.288	8.268	0.8298	0.2029
120	1093	156.4	94.4	71.65	4.857	66.49	2.927	6.789	13.64	1.527	0.2148
125	967	135.1	82.3	67.37	4.279	59.48	2.617	6.120	20.78	2.549	0.2204
130	858	116.9	71.9	62.5	3.769	51.18	2.252	5.305	29.43	3.858	0.2182
135	764	101.5	63.0	57.65	3.320	42.15	1.854	4.400	39.10	5.319	0.2077
140	682	88.3	55.3	52.59	2.925	33.04	1.453	3.472	49.16	6.715	0.1897
145	611	77.0	48.7	49.15	2.593	24.45	1.075	2.585	59.15	7.771	0.1653
150	548	67.3	42.9	45.67	2.298	16.71	0.7345	1.778	68.91	8.143	0.1357
155	492	58.9	37.9	42.19	2.037	9.88	0.4341	1.057	78.92	7.297	0.09997
160	439	50.8	33.1	38.59	1.806	3.74	0.1646	0.403	90.48	4.185	0.05365
165	389	44.6	30.0	36.09	1.607	1.29	0.05667	0.140	95.91	2.216	0.02330
170	349	40.2	26.6	33.58	1.430	0.854	0.03753	0.093	96.39	2.351	0.01598
175	314	35.6	23.7	31.11	1.272	0.663	0.02910	0.073	95.81	3.204	0.01236
180	283	31.4	21.1	28.57	1.132	0.535	0.02349	0.059	93.25	5.937	0.01024
185	255	28.2	18.9	26.81	1.004	0.415	0.01823	0.046	84.50	14.86	0.008128
190	231	25.1	17.0	24.88	0.890	0.340	0.01490	0.038	78.70	20.77	0.006774
195	210	22.4	15.3	23	0.789	0.292	0.01281	0.033	75.88	23.66	0.005919
200	192	20.0	13.7	21.19	0.700	0.257	0.01128	0.029	74.26	25.33	0.005285

The CDF II Detector



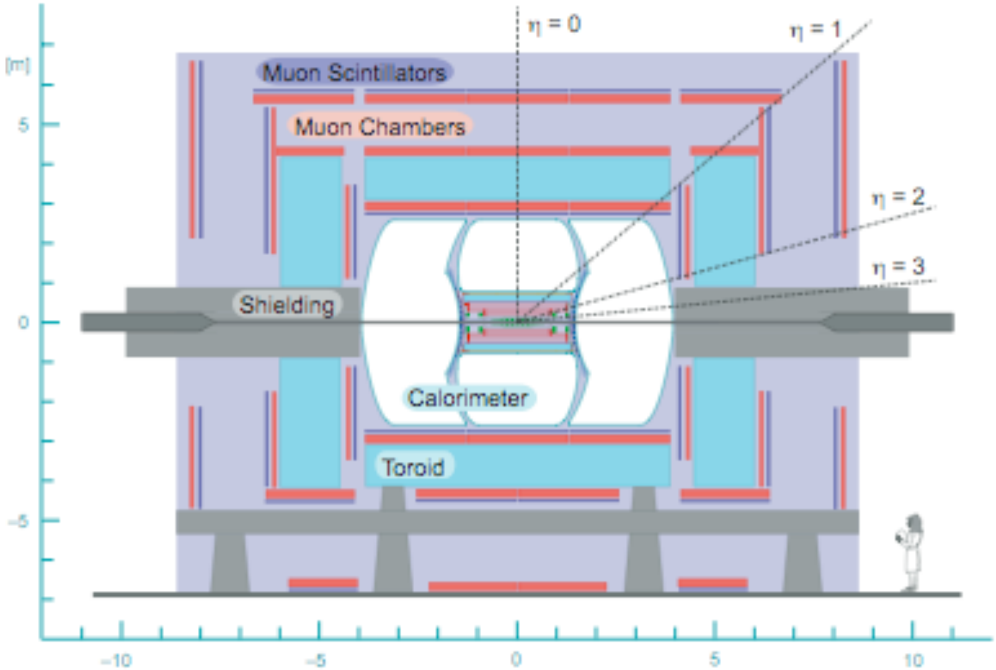
Lepton coverage:
$|\eta| < 1.5$ (muons)
$|\eta| < 2.0$ (electrons)

b-tagging with
$|\eta| < \sim 1.4$

Jets to
$|\eta| < 2.8$
Higgs analyses
restrict to
$|\eta| < 2.0$

Dijet mass
resolution: ~16%

The DØ Detector



Lepton coverage:

|η| < 2 (muons)

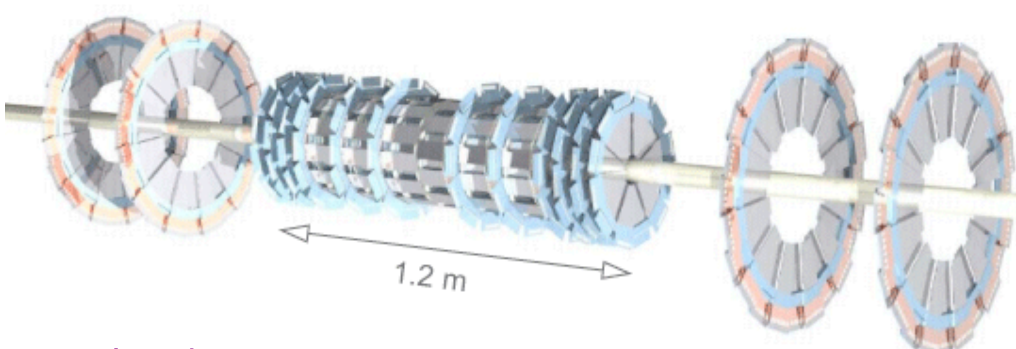
|η| < 2.6 (electrons)

b-tagging with

|η| < ~2

Jets to

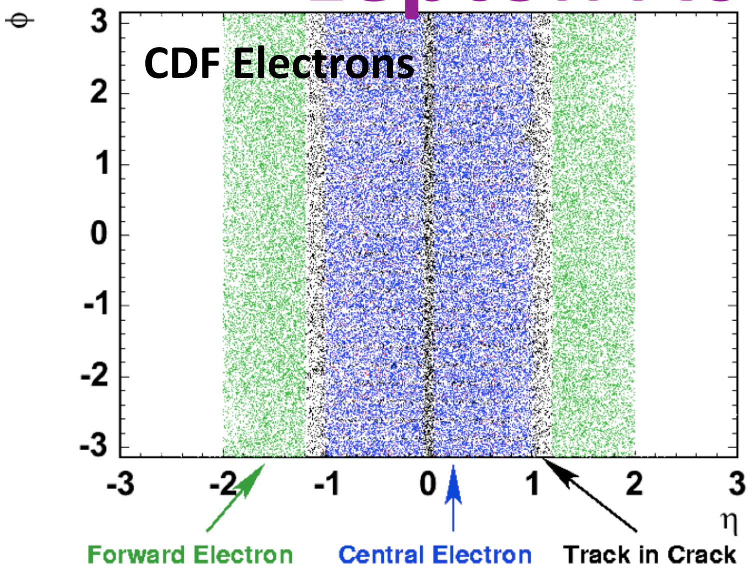
|η| < 3



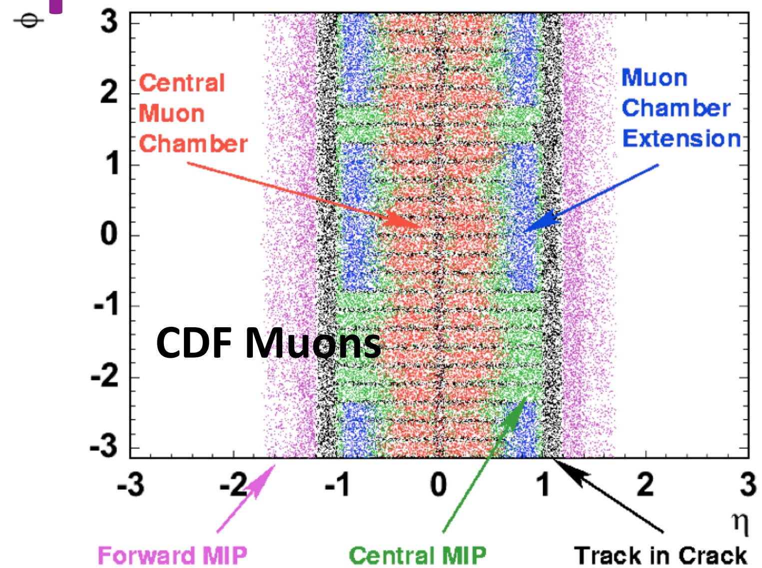
Similar dijet mass resolution to CDF

New Innermost Silicon Layer added between Run IIa and Run IIb

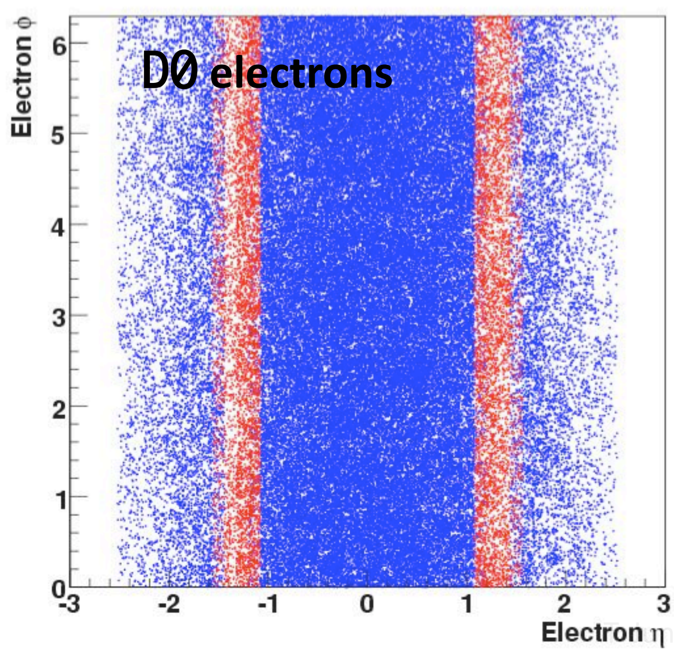
Lepton Acceptance Gains



10% gain in CDF electron acceptance



30% gain in CDF single-muon acceptance



Inter-calorimeter electrons
-- 10% gain in D0 electron acceptance

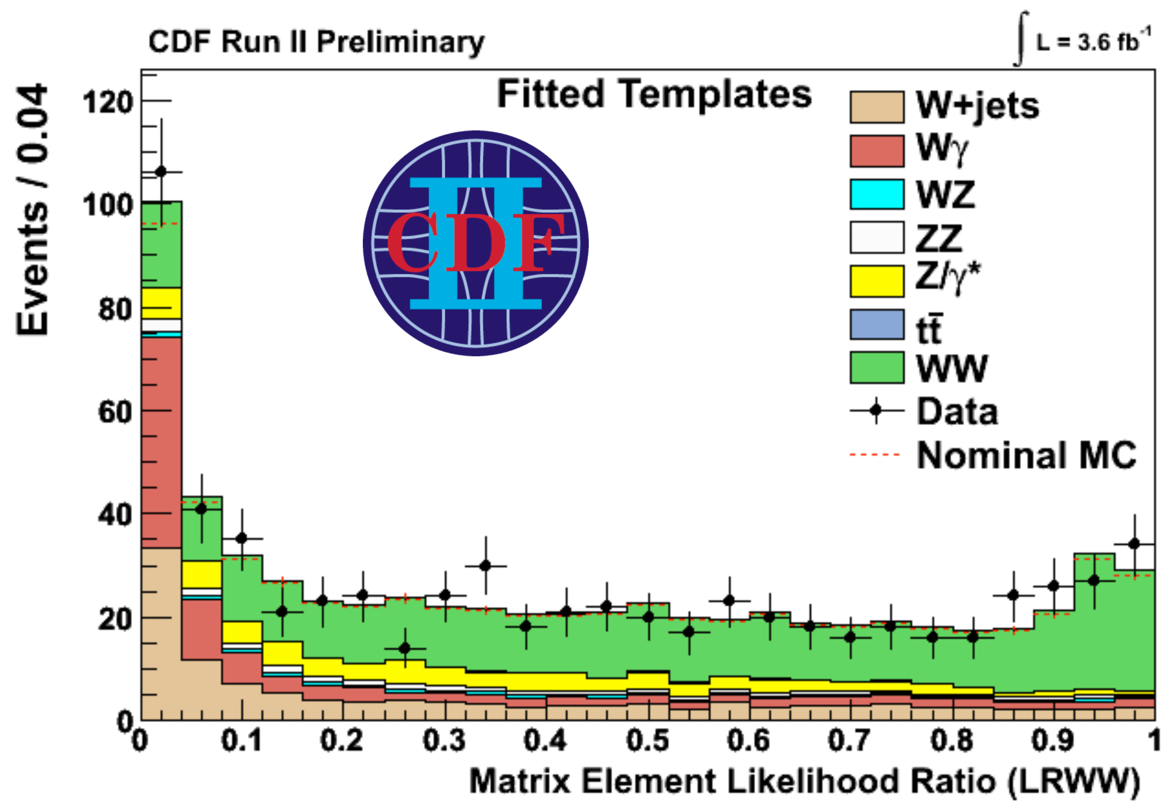
These Leptons don't all trigger!
Use another lepton, or MET+Jets triggers.

WW Cross Section Measurement

Signal model: MC@NLO

Checks Matrix Element discriminant shape of dominant background in the signal sample

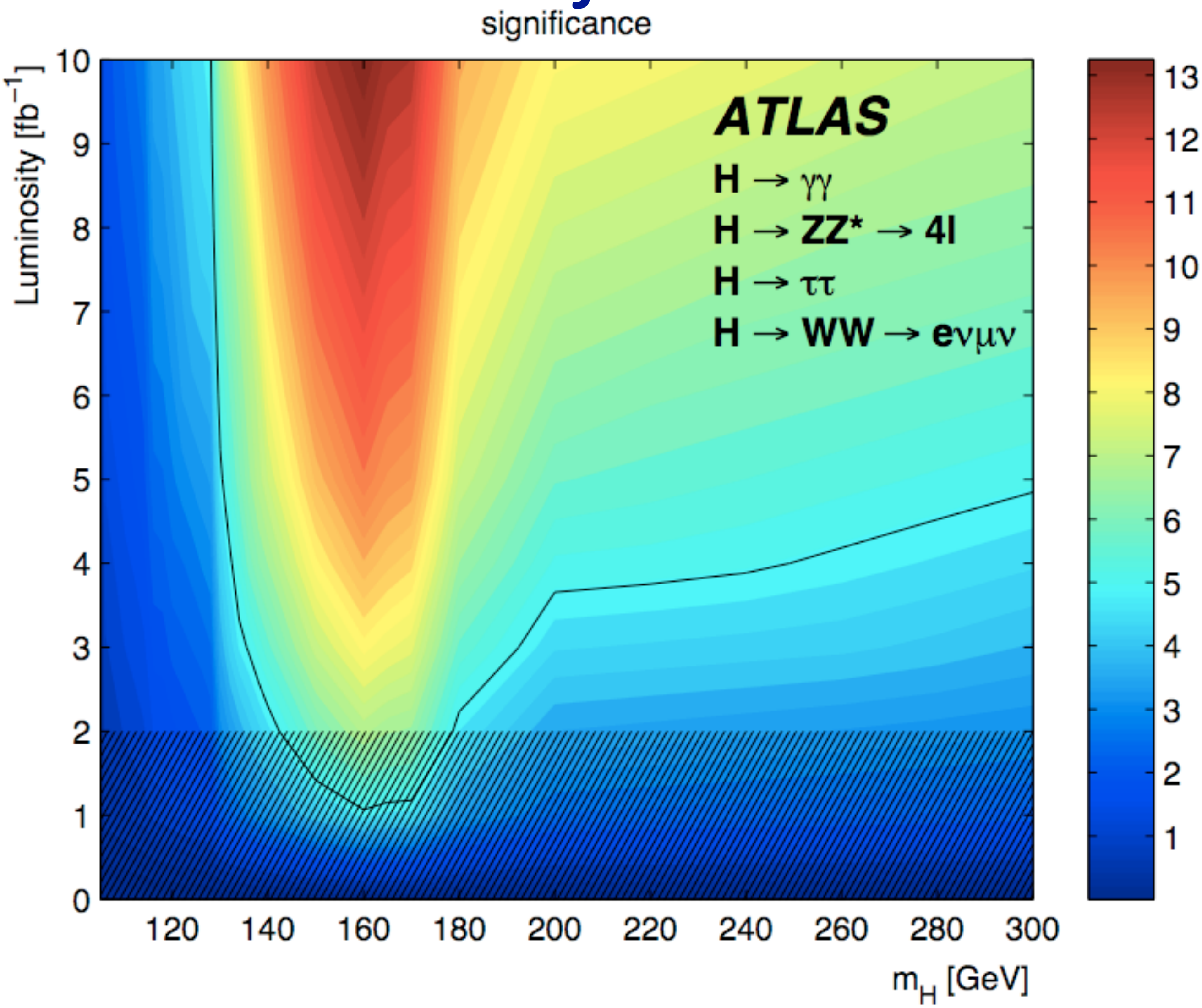
Same as Higgs search but reverse roles of signal and background



$$\sigma(p\bar{p} \to W^+W^-) = 12.1 \pm 0.9\ (\text{stat})\ ^{+1.6}_{-1.4}\ (\text{syst})\ [\text{pb}]$$

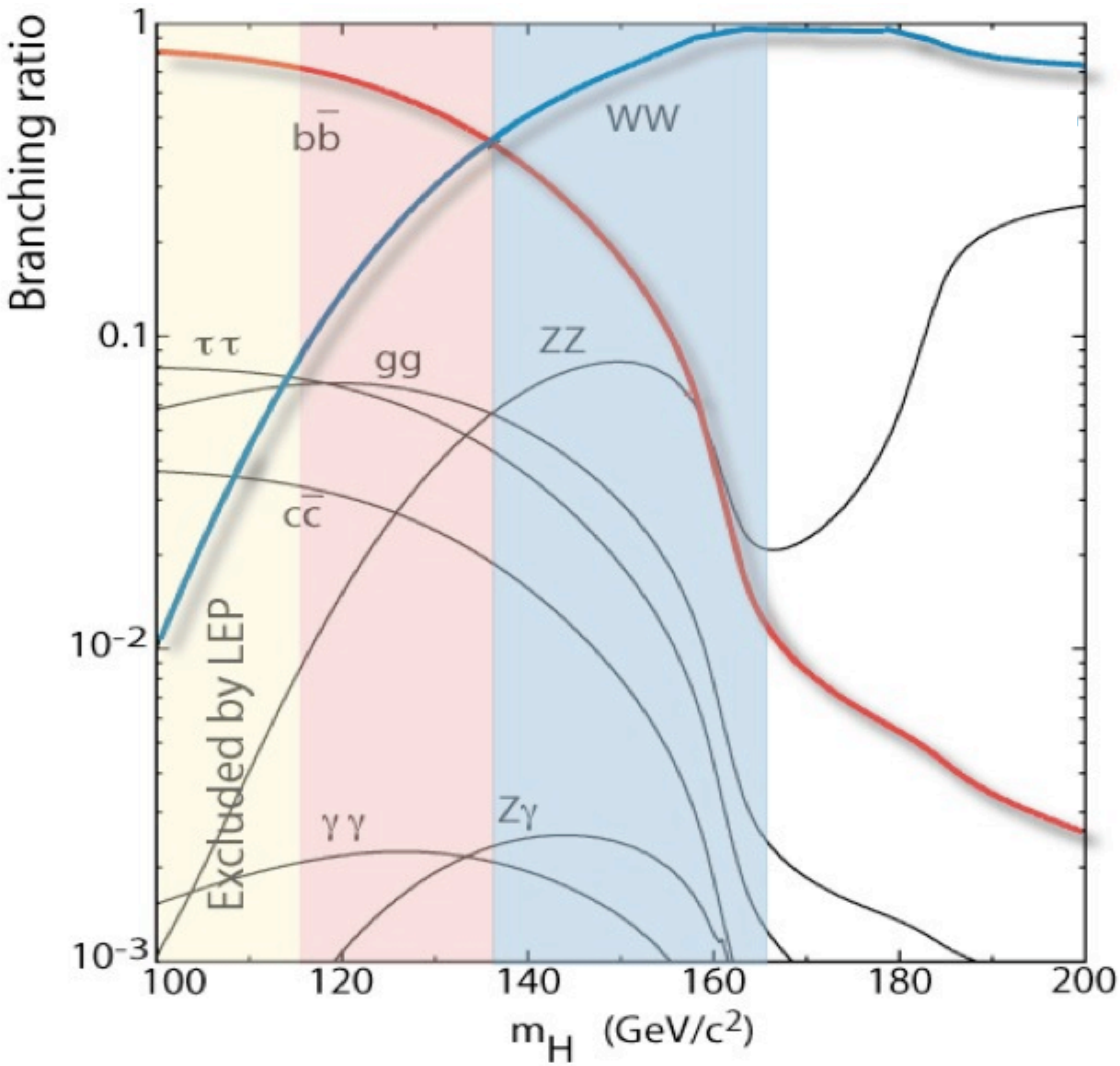
SM: 12.4 ± 0.7 pb (MCFM)

ATLAS's Projections



CERN-OPEN-2008-020, "Expected Performance of the ATLAS Experiment": arXiv:0901.0512v3 [hep-ex]

Standard Model Higgs Boson Decay Branching Fractions



HDECAY by
M. Spira

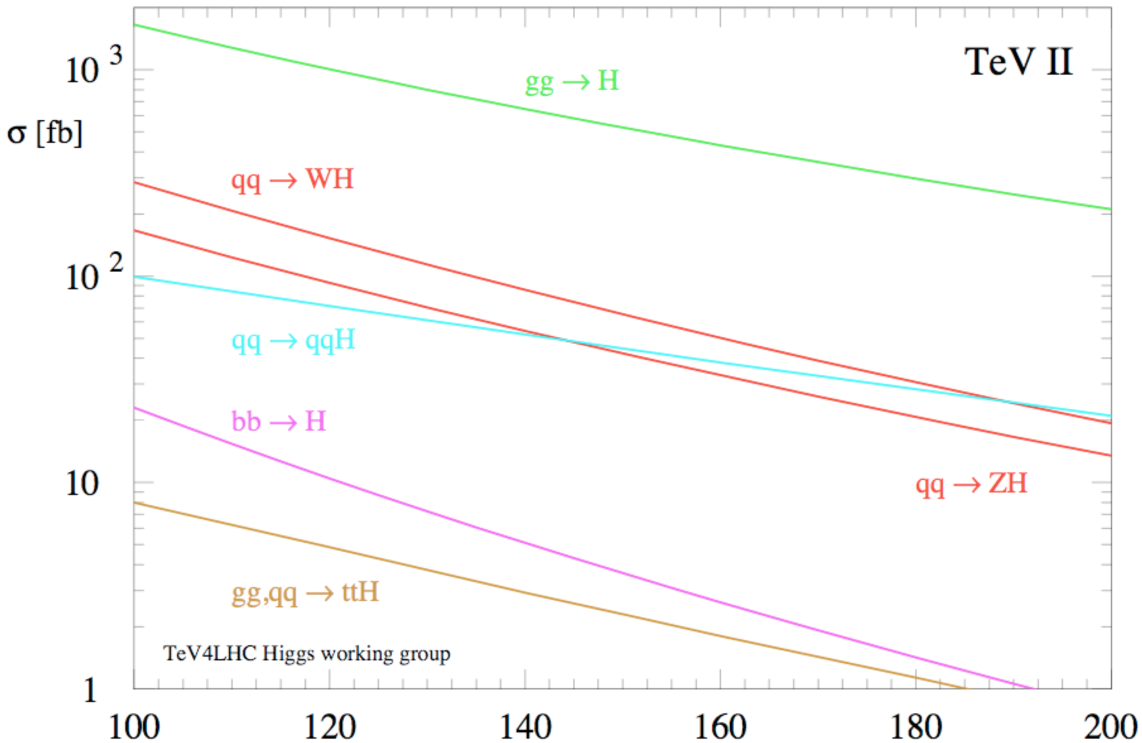
114.4 < m_H < 135 GeV:
H→bb dominates.

gg→H→bb drowned by gg→bb. Use WH, ZH.

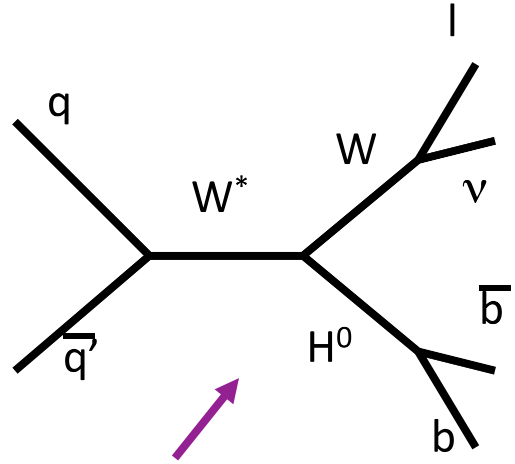
135 < m_H < 200 GeV
H→W^+W^- dominates

gg→H, WH, ZH, VBF all can be used

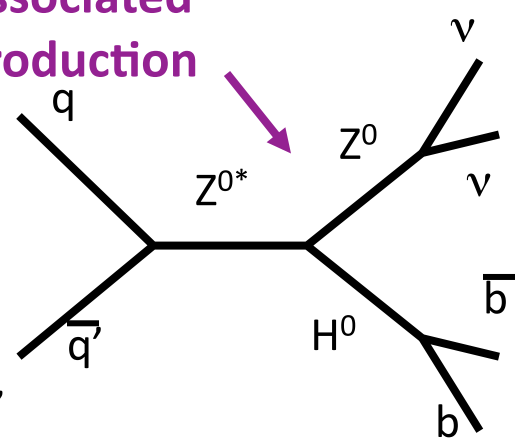
SM Higgs Boson Production Mechanisms



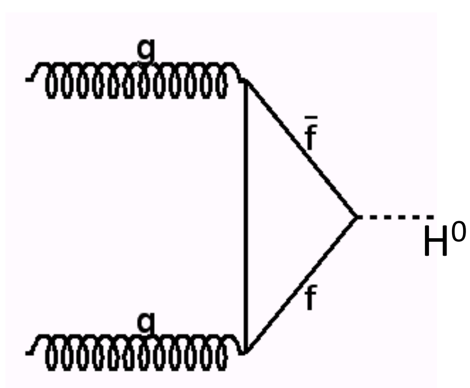
http://maltoni.home.cern.ch/maltoni/TeV4LHC/SM.html
and references therein.

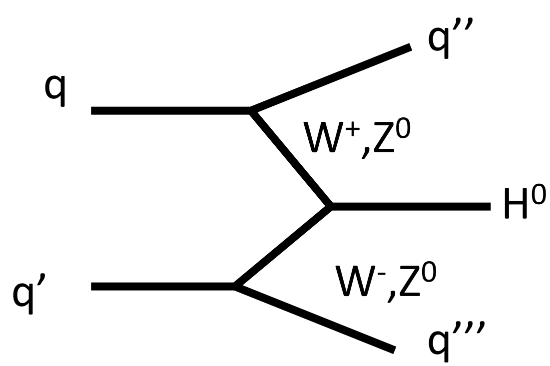


Associated Production



gluon fusion





Vector-Boson Fusion (VBF)

Studies of Injecting a Signal at m_H=115 GeV

- lvbb, METbb, and llbb channels included
- Inject SM*1.0 signal at m_H=115 GeV on top of SM backgrounds, and generate pseudoexperiments with that.
- Analyze 115 signal+background pseudoexperiments at other test masses – 100 GeV to 150 GeV
- Find the median expected limit assuming signal is there (compute it just as you would without the signal) and compare with the distribution of limits assuming the signal is completely absent.