LOW MASS HIGGS SEARCHES AT TEVATRON

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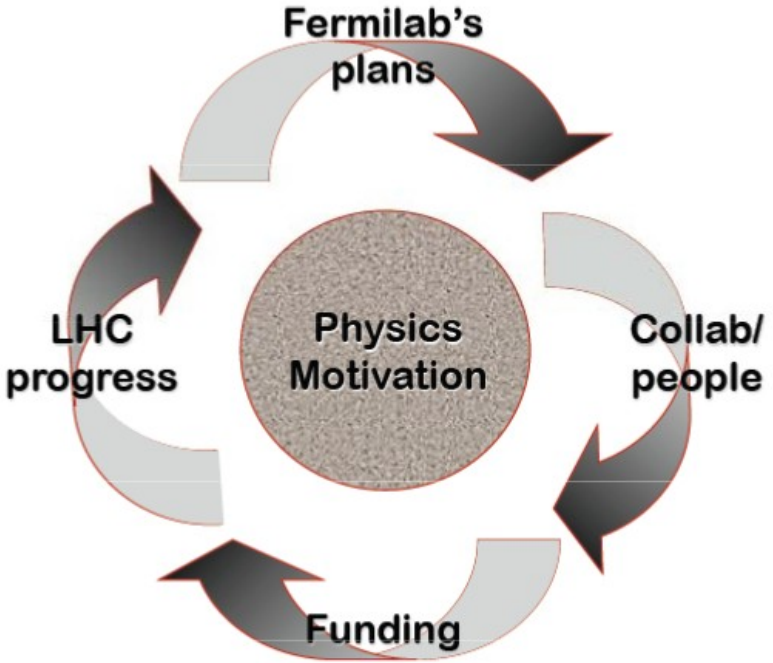
on behalf of the DØ and CDF collaboration

OUTLINE

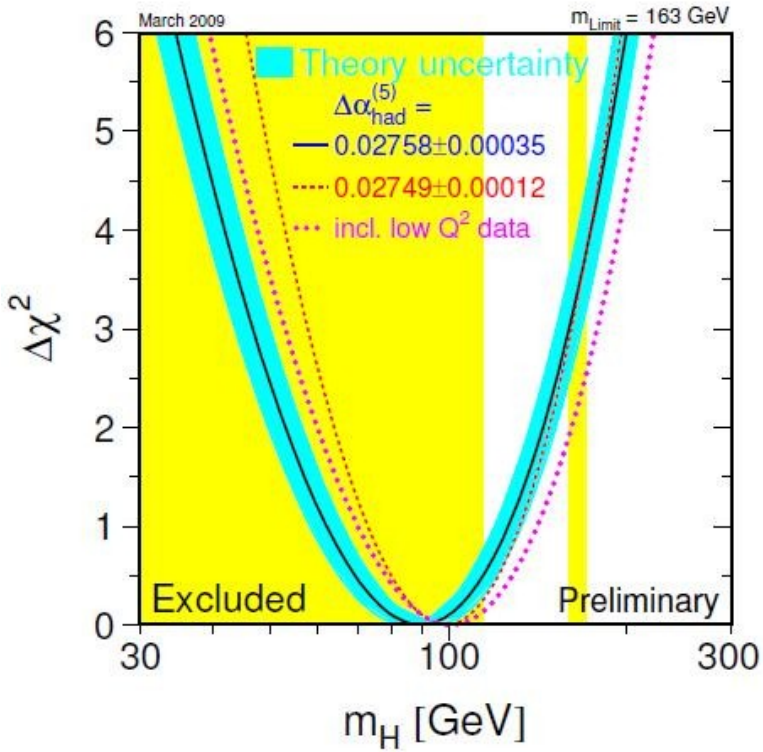
- MOTIVATION / HIGGS PRODUCTION
- TEVATRON / CDF AND DØ DETECTORS
- ANALYSES
- COMBINATION
- SUMMARY

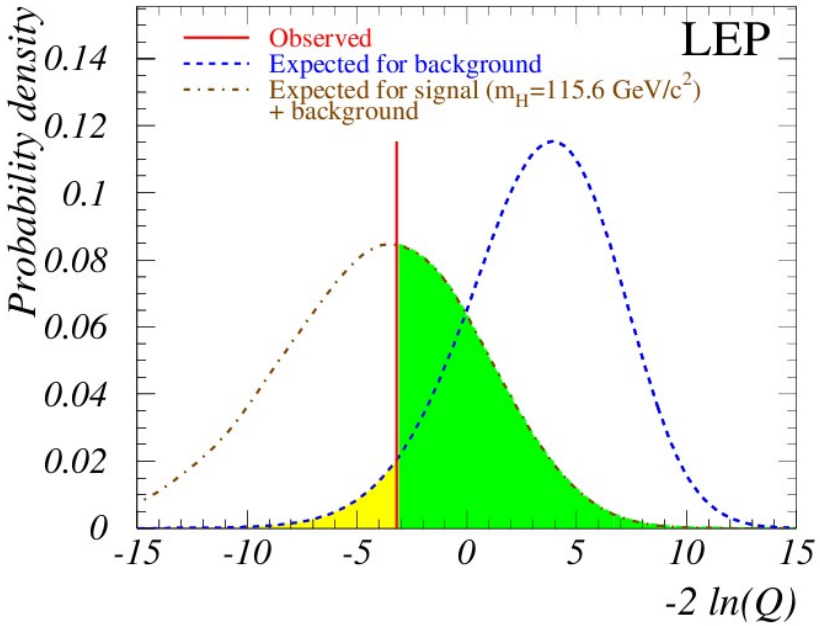


STANDARD MODEL HIGGS

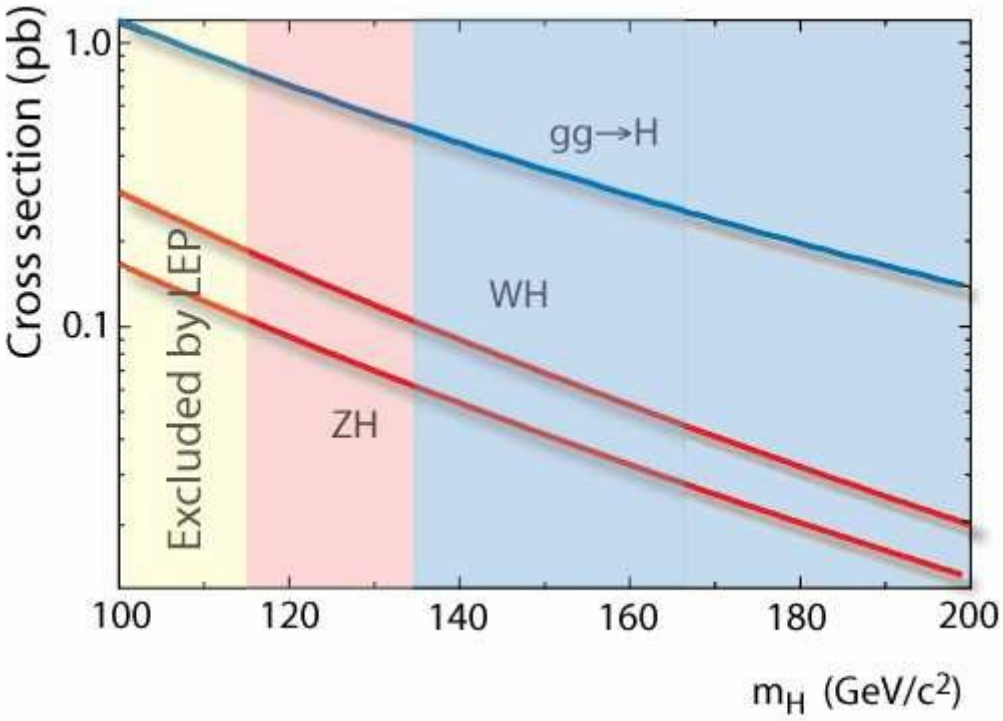
– Electroweak symmetry breaking → generate vector boson mass.
– The simplest mechanism is the standard model higgs, with a complex doublet scalar fields.

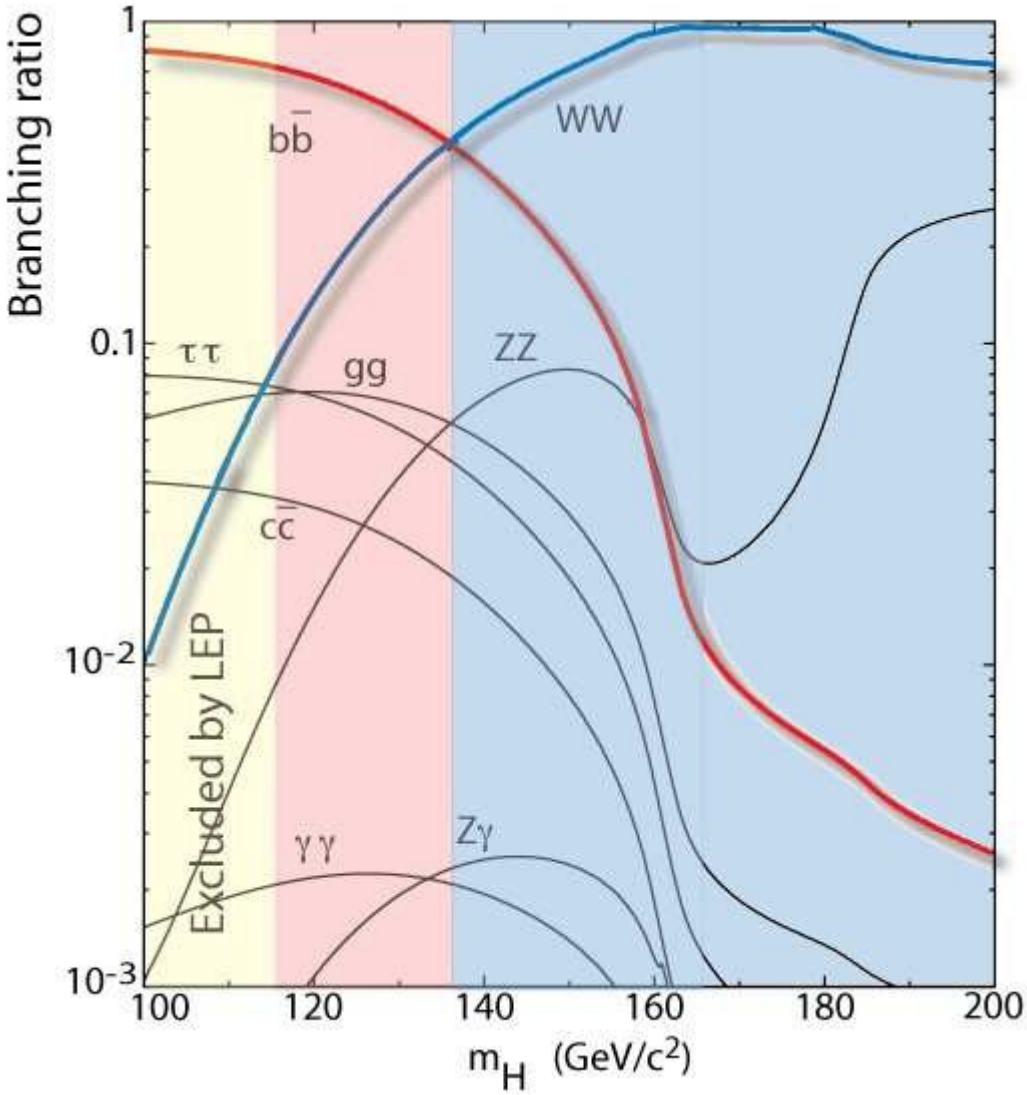
“The Higgs Boson is the last missing particle in the Standard Model.”





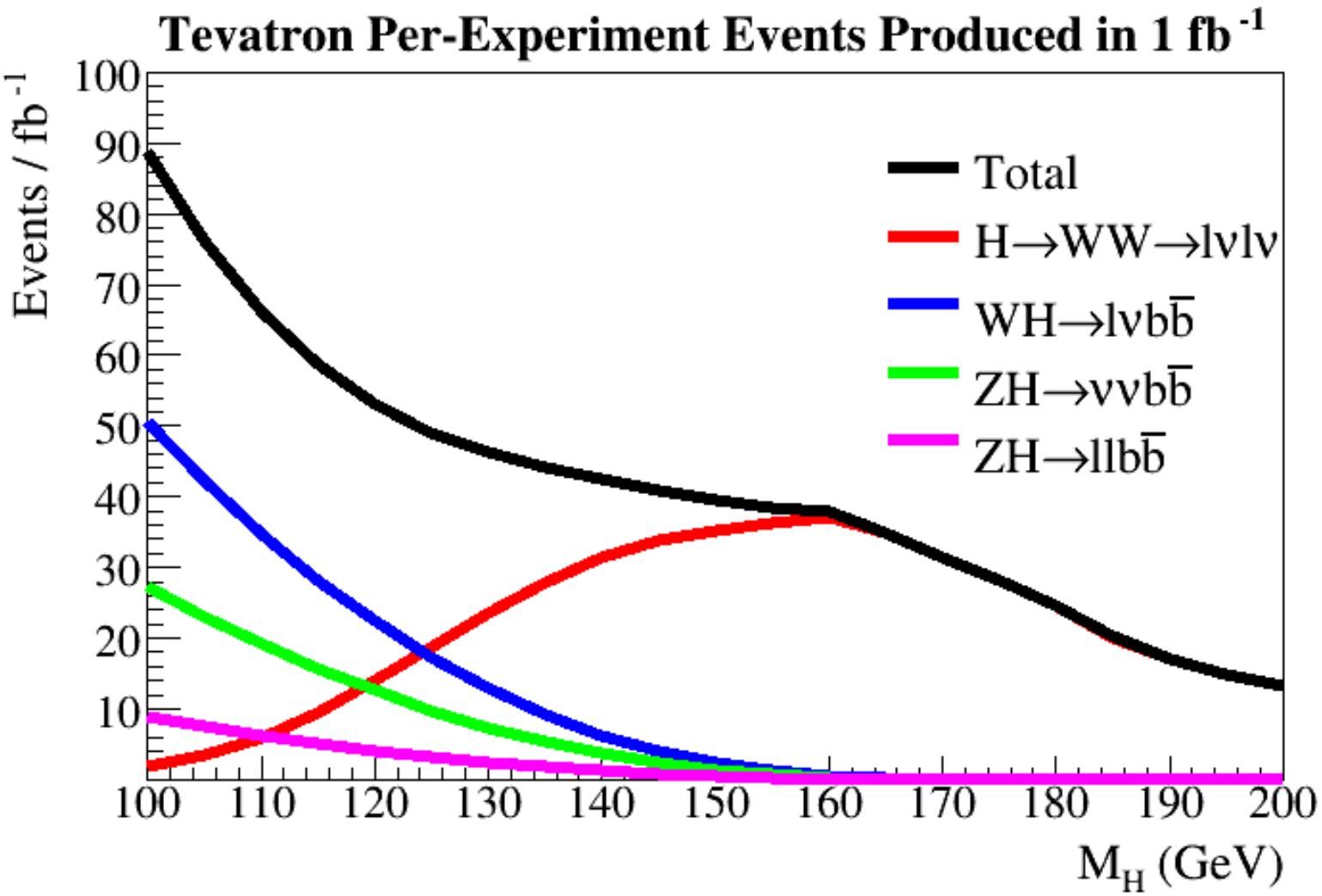
HIGGS PRODUCTION AT TEVATRON





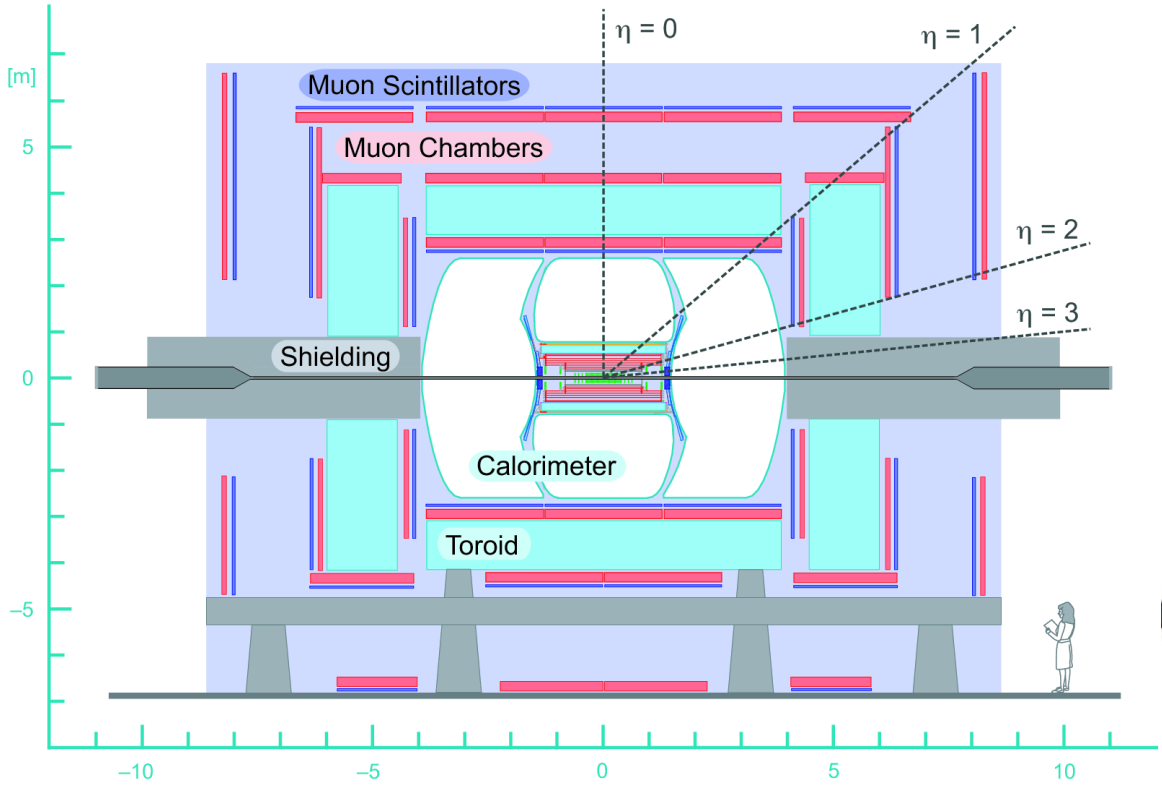
Most sensitive channels are the associate production VH(→bb) at low mass and gluon fusion H(→WW) at high mass.

HIGGS PRODUCTION AT TEVATRON



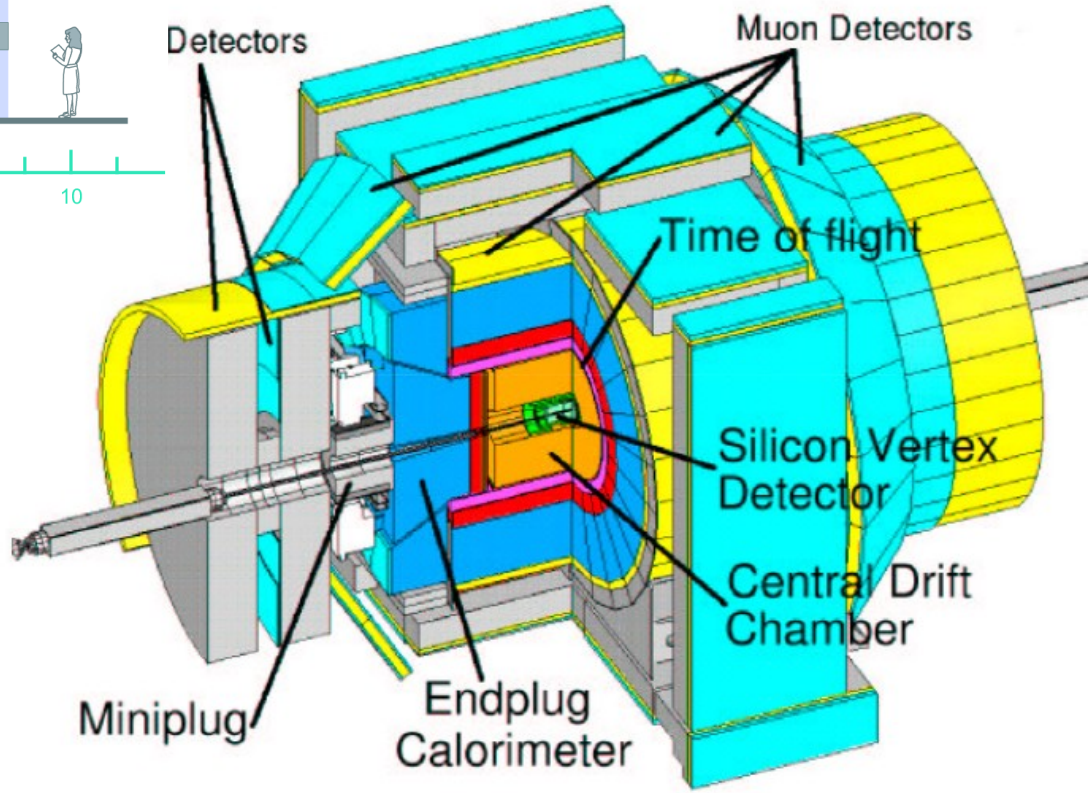
Most sensitive channels are the associate production VH(→bb) at low mass and gluon fusion H(→WW) at high mass.

THE DETECTORS

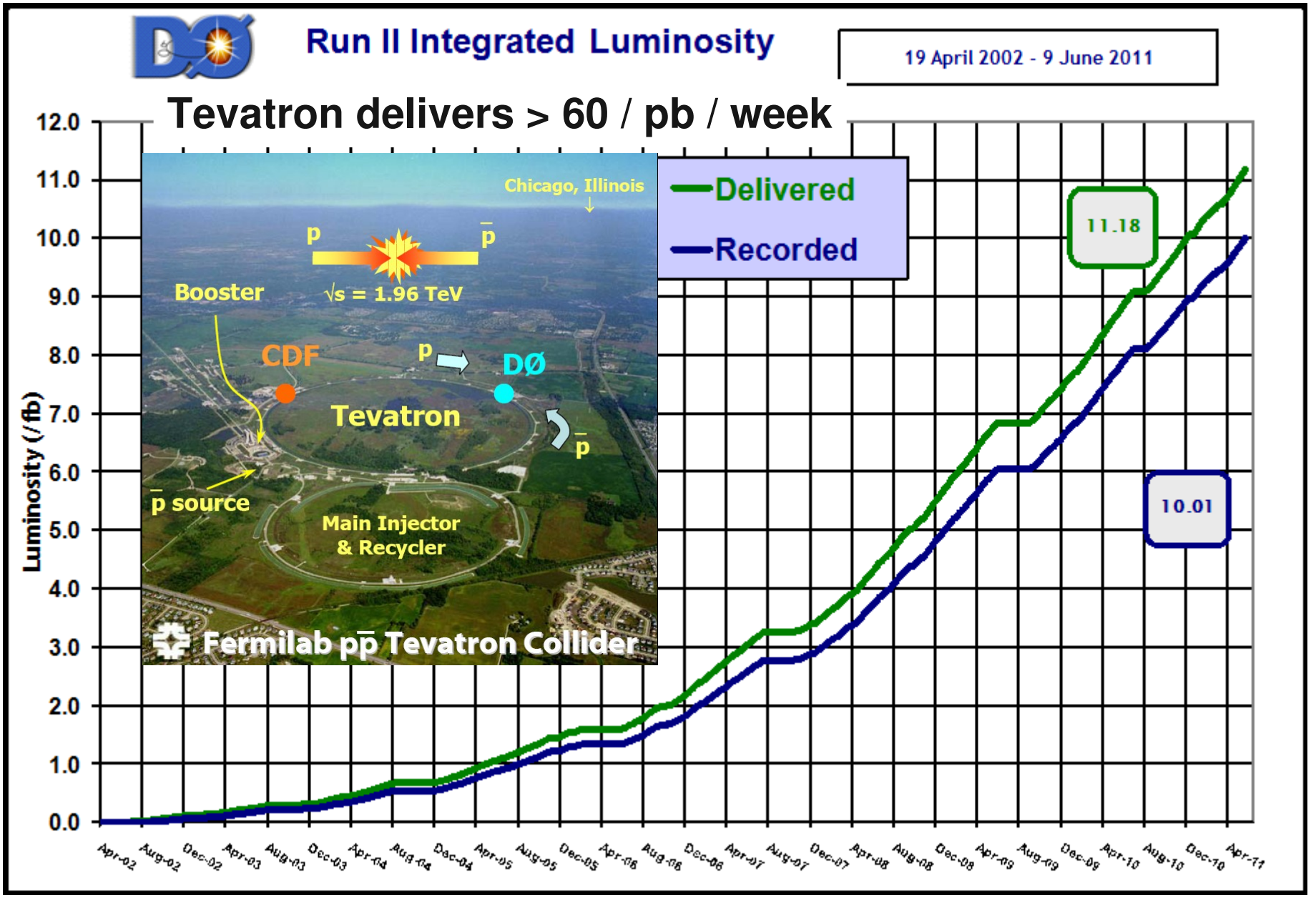


Detectors Coverage (η):

- **Muons ~ 2.0**
- **Tracking ~ 2.5**
- **EM/Jets ~ 4.0**



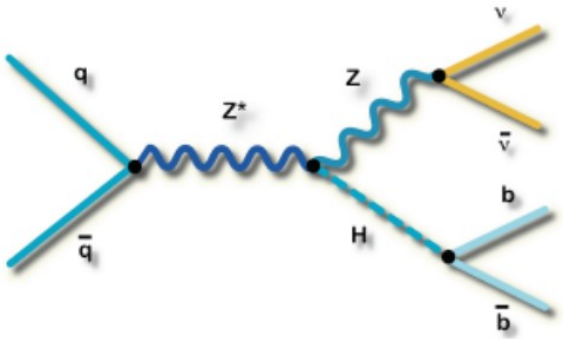
- → **Lepton identification**
- → **Missing E_T (MET)**
- → **Jet reconstruction**
- → **b-jet selection**



Analyzed data goes up to 6.7/fb (very soon to be updated)

Run until September 2011 → 11/fb for final results

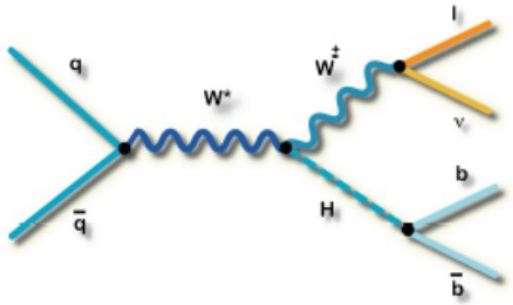
MAIN LOW MASS CHANNELS



MET+jets

– large signal cross section

– large QCD and EW background rates

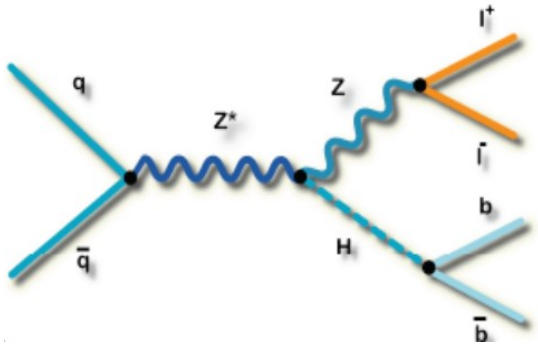


MET+lepton+jets

– large signal cross section

– large EW background rates

– small QCD background rates



2 leptons + jets

– low background rates

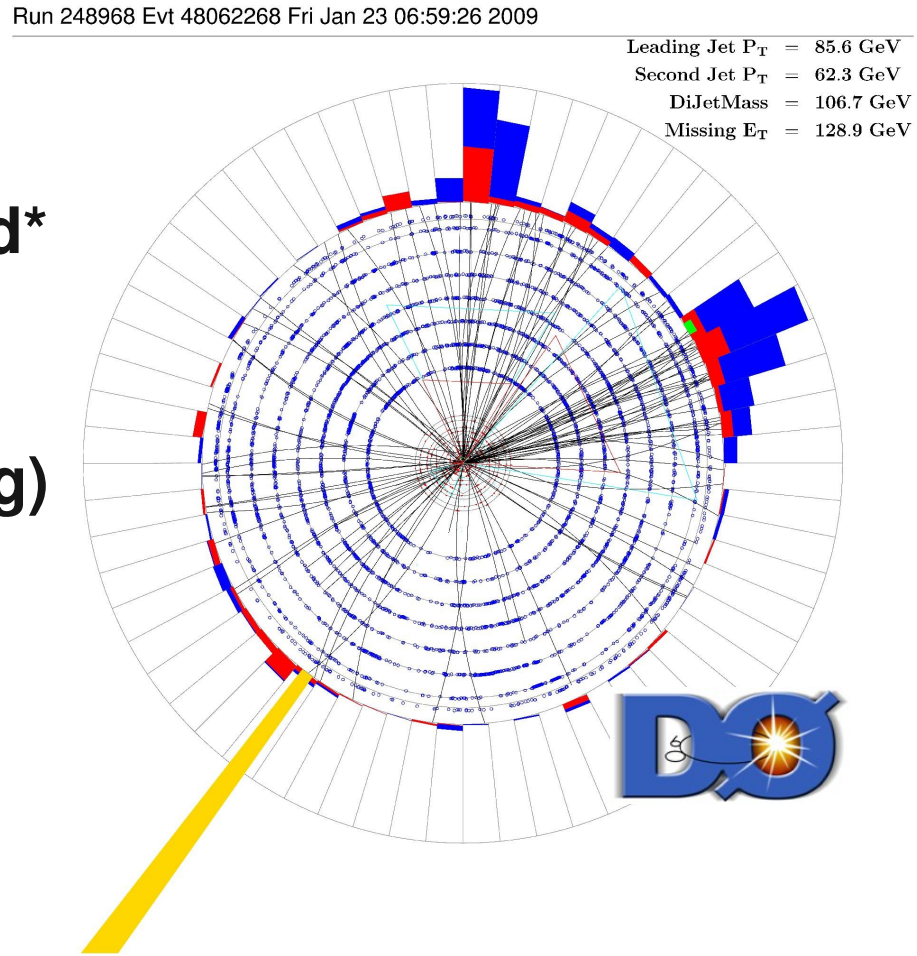
– low signal cross section

MET + JETS (1)

– Large MET
– 2 or 3 collinear high p_T jets
– Electron and Muon vetoes
– Dedicated QCD background rejection
– b-jet tagging

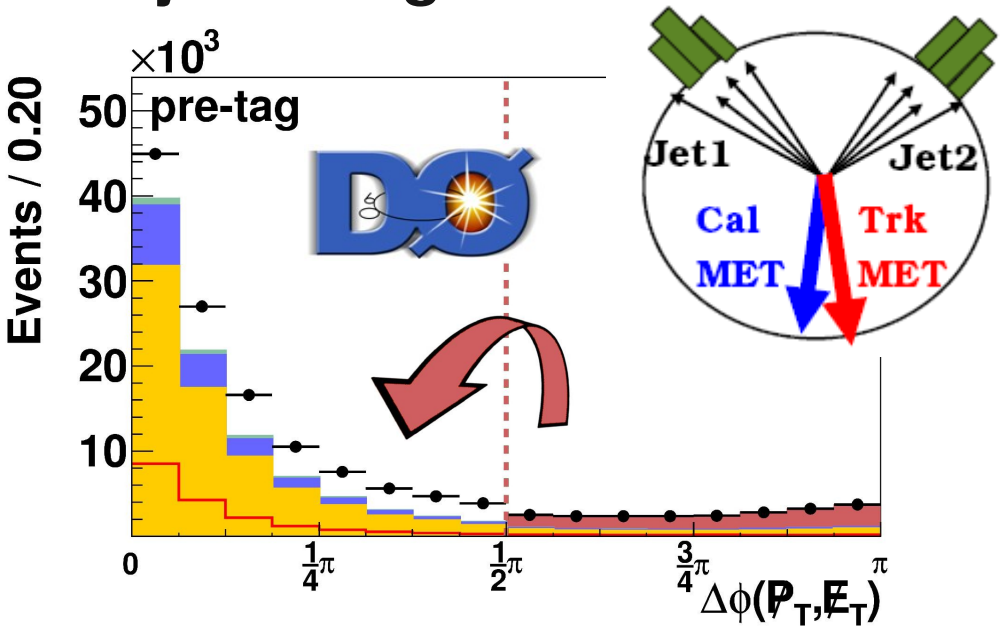
WH signal is also selected when the lepton is not identified

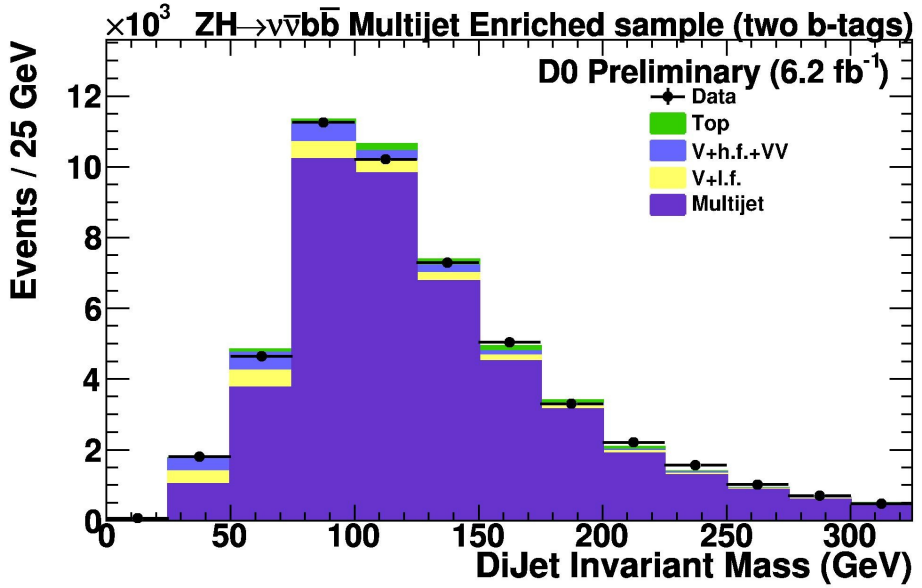
Two final samples
→ 2 b-jet candidates (double tag)
~ 90% of the sensitivity
→ 1 b-jet candidate (single tag)
~10% of the sensitivity



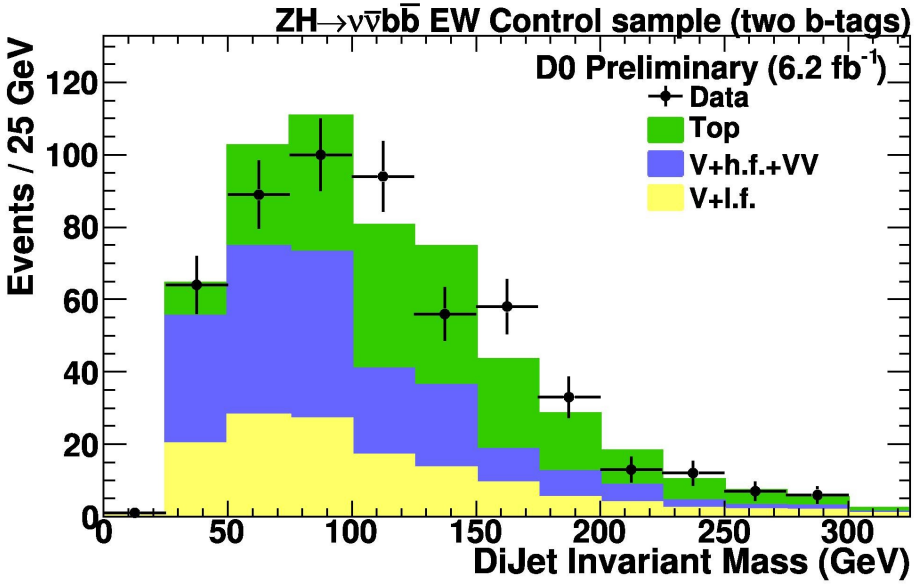
MET + JETS (2)

Multijet Background modeled from DATA sideband





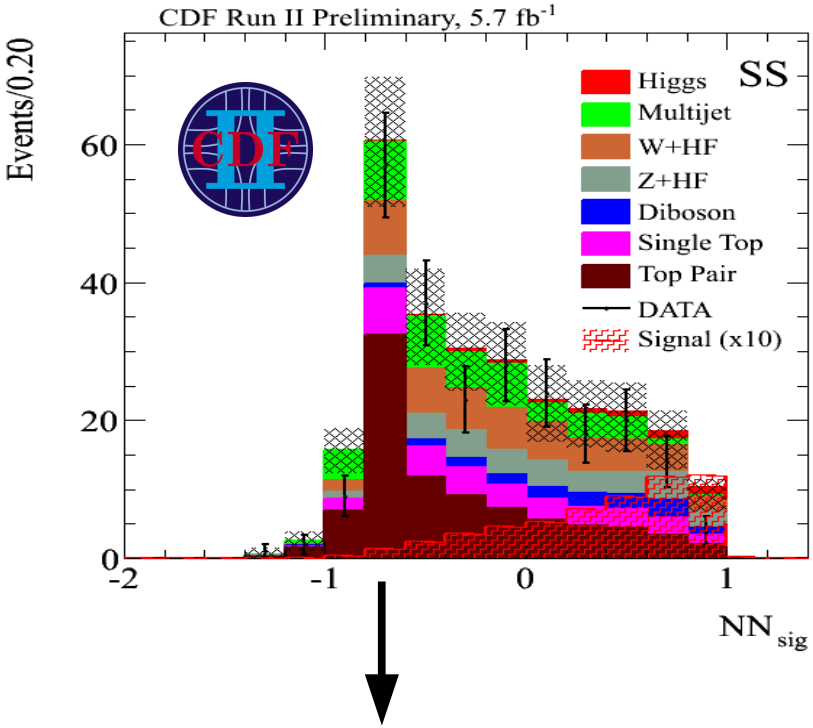
SM Background modeled from simulation and tested in control samples.

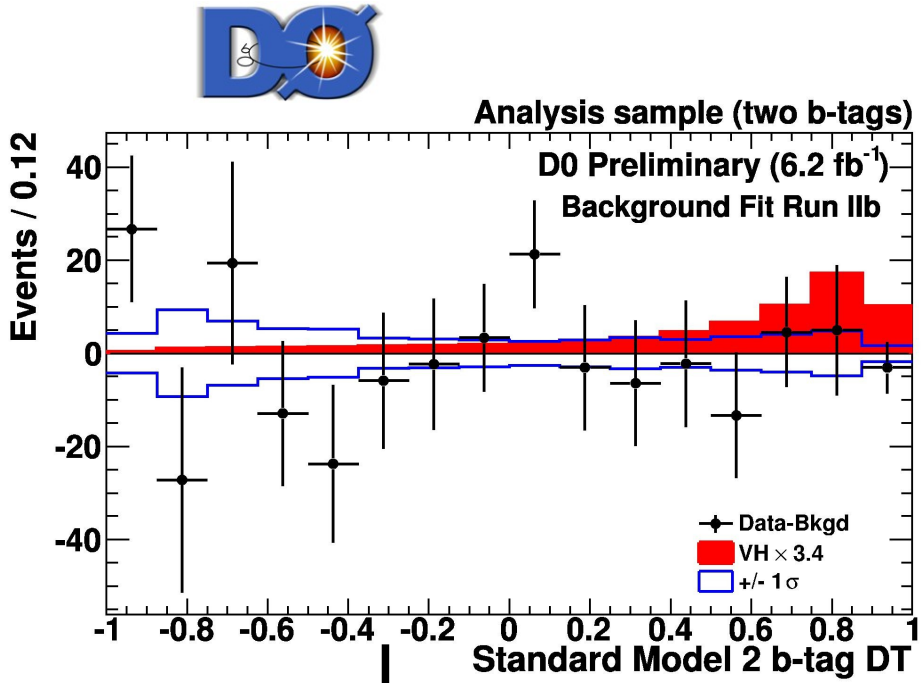


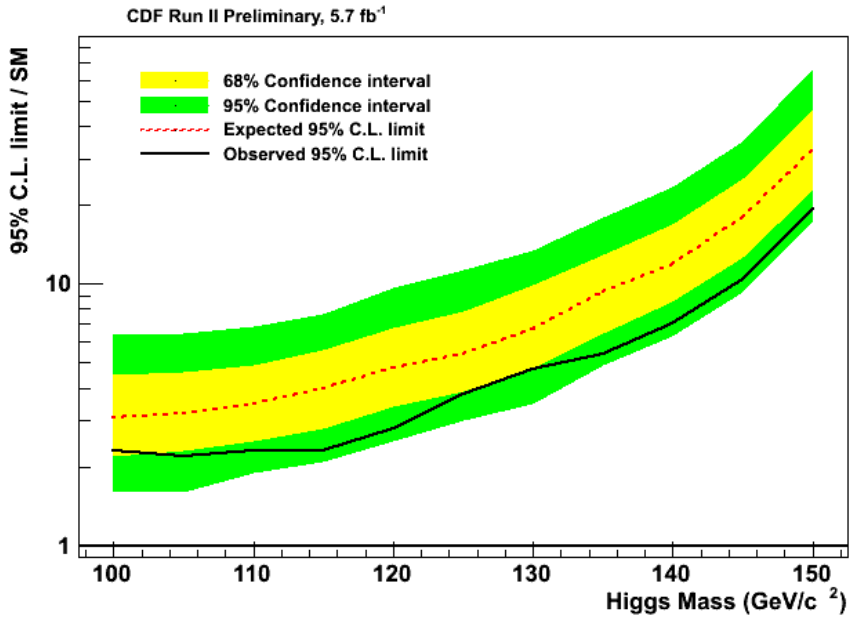
MET + JETS (3)

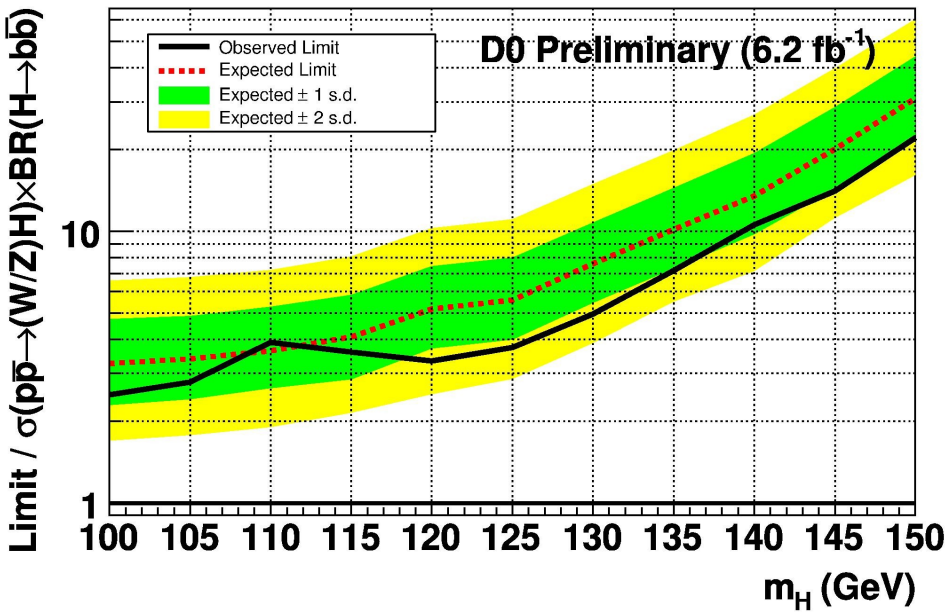
Systematic Uncertainty	Signal (%)	Background (%)
Single Tag		
Jet EC - Jet ER	2.1	2.9
Jet R&T	3.4	2.9
b Tagging	7.0	4.3
Trigger	2.0	1.8
Lepton identification	0.4	0.3
Heavy Flavor Fractions	-	4.2
Cross Sections	6	6.4
Luminosity	6.1	5.5
Multijet Normalization	-	2.1
Total	11.9	10.8
Double Tag		
Jet EC - Jet ER	0.4	1.1
Jet R&T	3.3	3.2
b Tagging	9.5	7.4
Trigger	2.0	1.9
Lepton identification	0.4	0.5
Heavy Flavor Fractions	-	7.3
Cross Sections	6.0	7.2
Luminosity	6.1	5.7
Multijet Normalization	-	1.5
Total	13.4	13.4

MET + JETS (4)


CDF Run II Preliminary, 5.7 fb-1
SS
Higgs
Multijet
W+HF
Z+HF
Diboson
Single Top
Top Pair
DATA
Signal (x10)
Events/0.20
NN sig


Analysis sample (two b-tags)
D0 Preliminary (6.2 fb-1)
Background Fit Run IIb
Data-Bkgd
VH × 3.4
+/- 1σ
Events / 0.12
Standard Model 2 b-tag DT


CDF Run II Preliminary, 5.7 fb-1
68% Confidence interval
95% Confidence interval
Expected 95% C.L. limit
Observed 95% C.L. limit
95% C.L. limit / SM
Higgs Mass (GeV/c 2)


Observed Limit
Expected Limit
Expected ± 1 s.d.
Expected ± 2 s.d.
D0 Preliminary (6.2 fb-1)
Limit / σ(pp̄→(W/Z)H)×BR(H→bb̄)
mH (GeV)

LEPTON + MET + JETS (1)

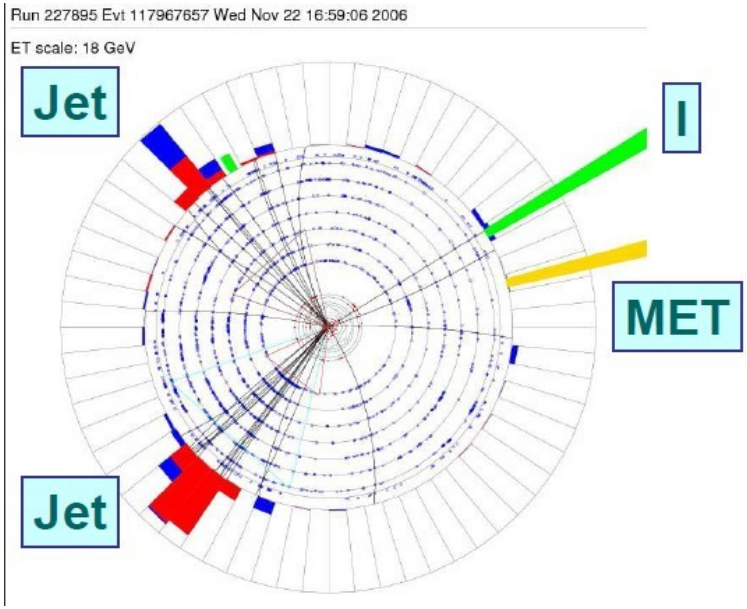
– Isolated high p_T electrons or muons

– Large MET

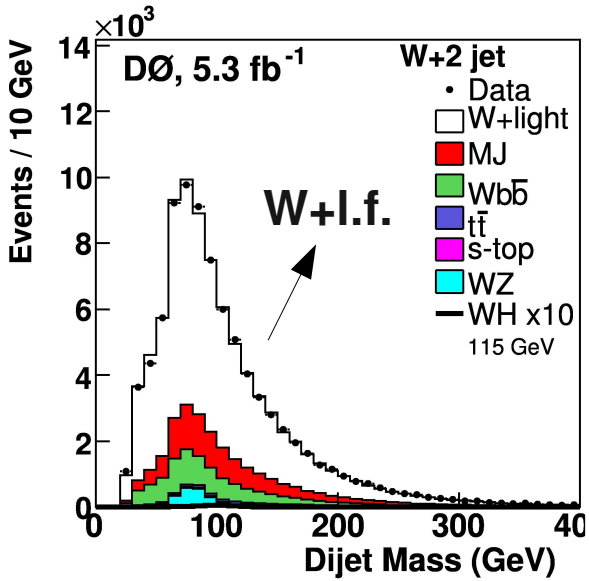
– split 2 and 3 jets events

– b-jet tagging

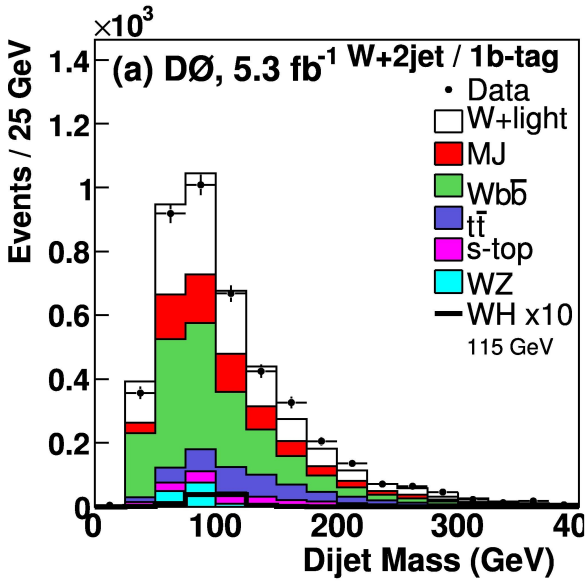
(efficiency ~ 50-70% | fake rate ~ 0.5-5%)



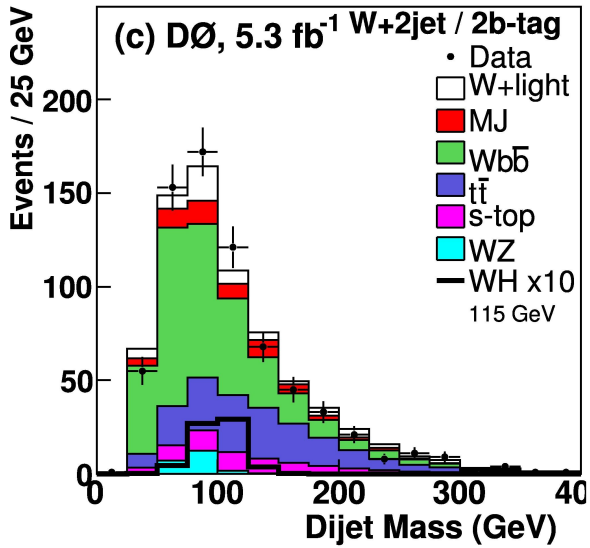
No b-jet tag required



1 b-jet tag required

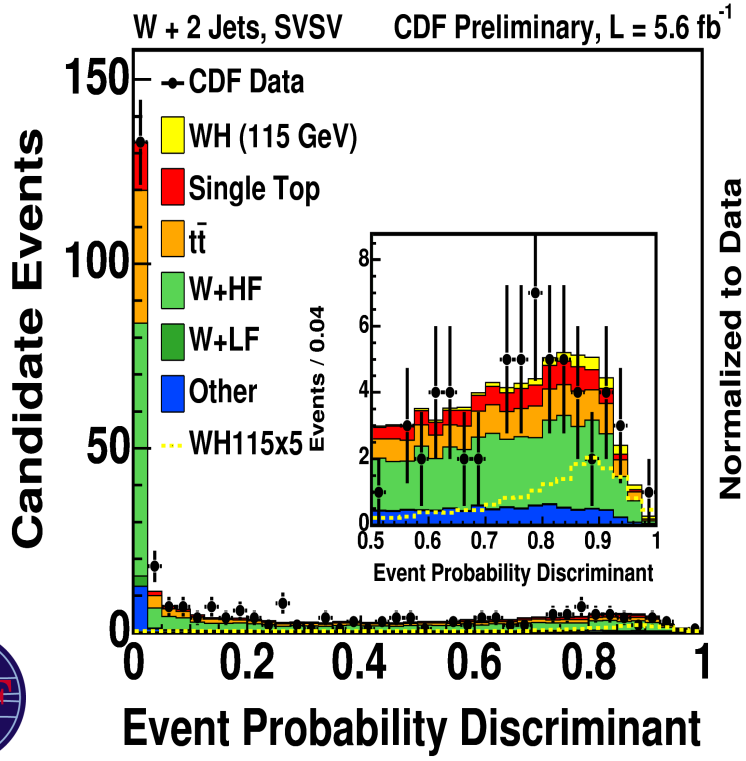


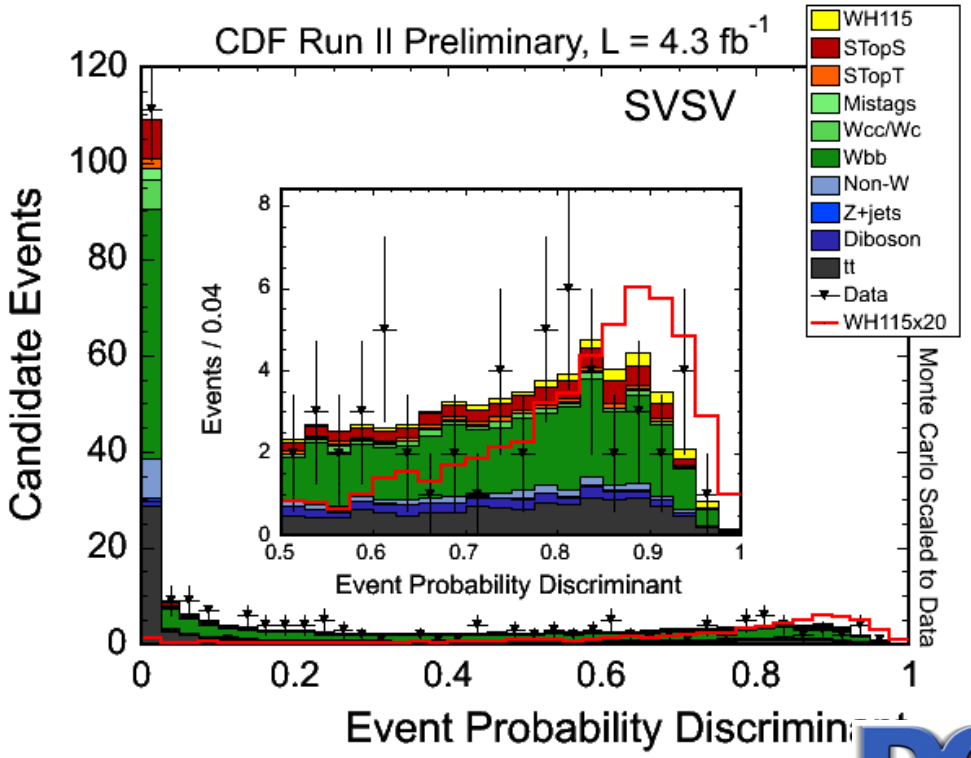
2 b-jets tag required

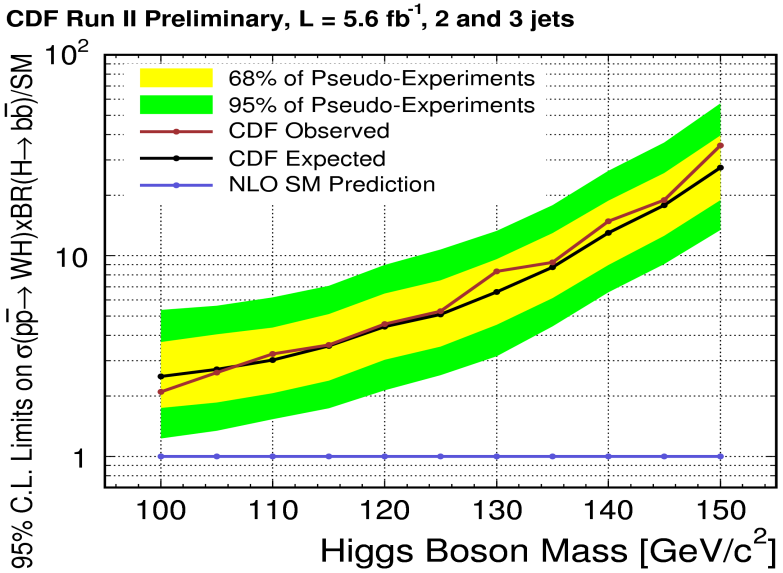


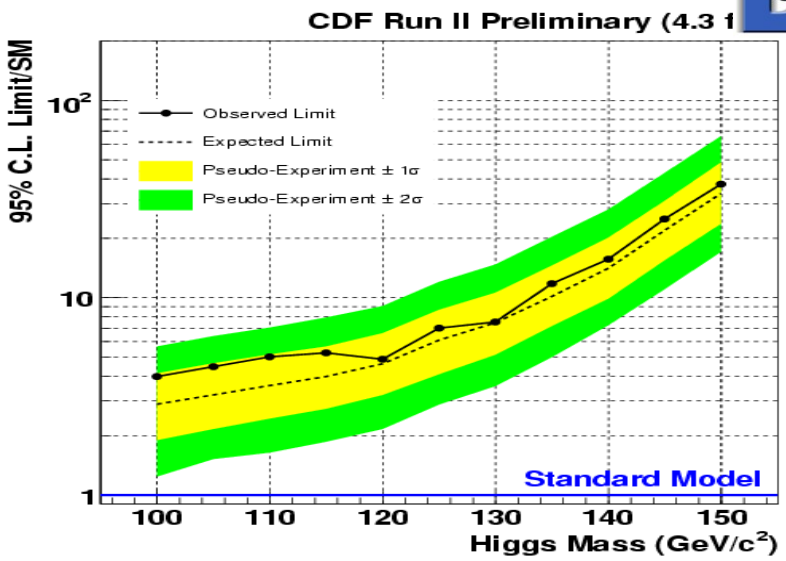
LEPTON + MET + JETS (2)

Final Distributions used for limits:





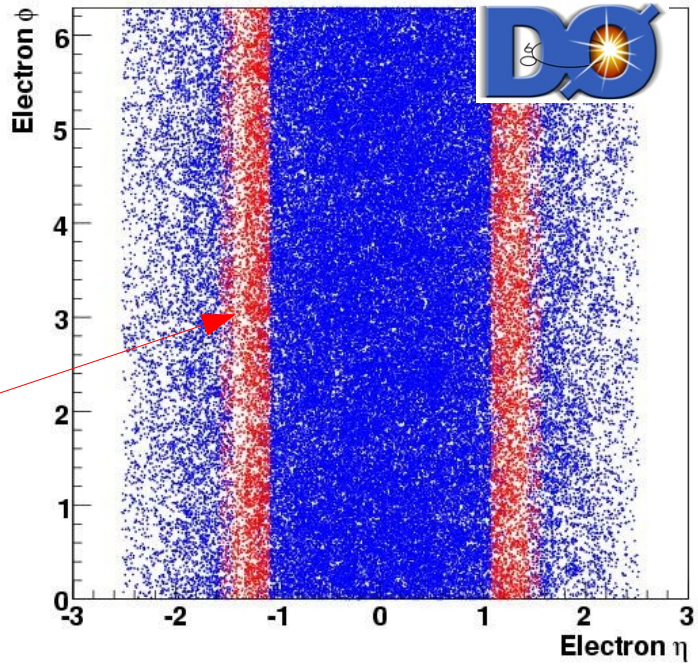


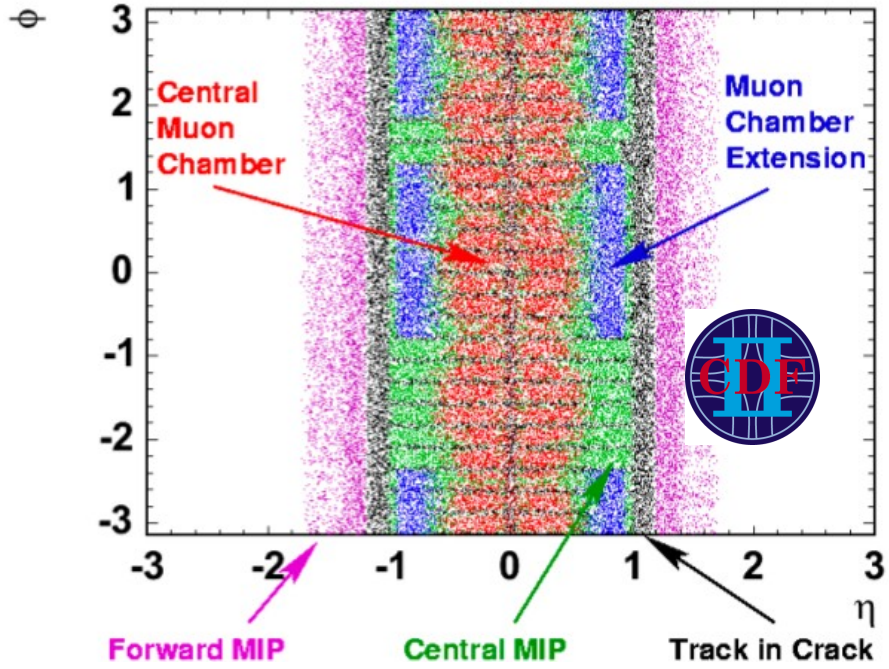


DI-LEPTON + JETS (1)

- Two isolated high p_T electrons or muons
- 2 or 3 jets
- b-jet tagging
- Low background, but low signal rate
  - → increase acceptance of lepton reconstruction (15%)
  - → use di-lepton system to constrain di-jet mass (15%)

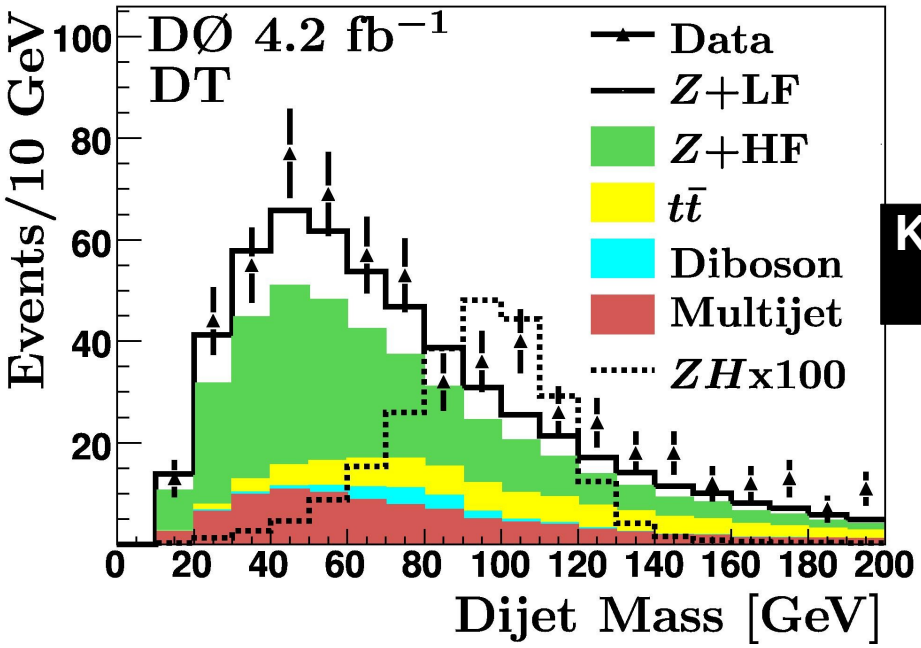
Electrons in the crack



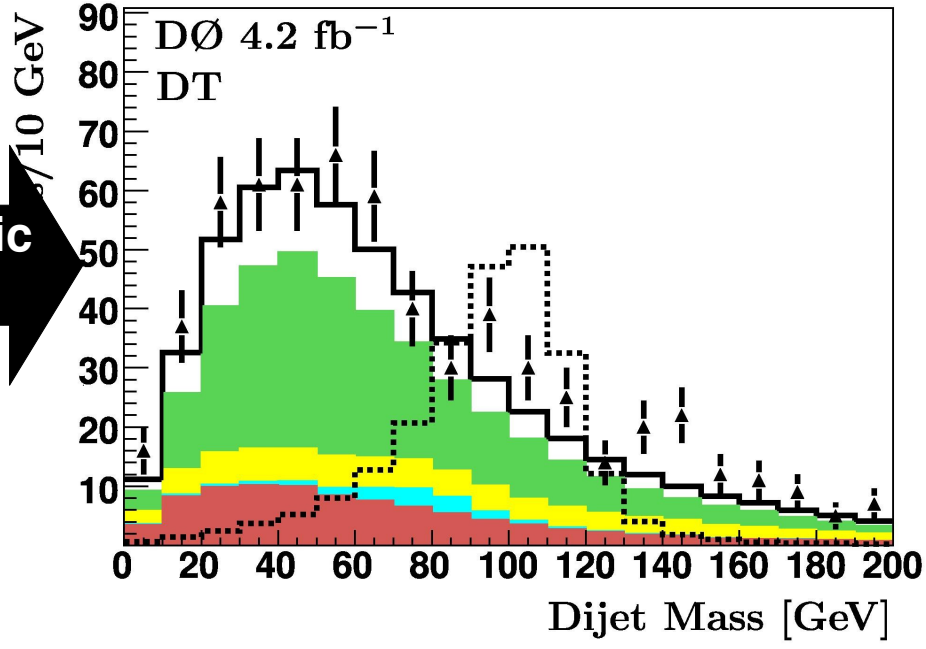


DI-LEPTON + JETS (2)

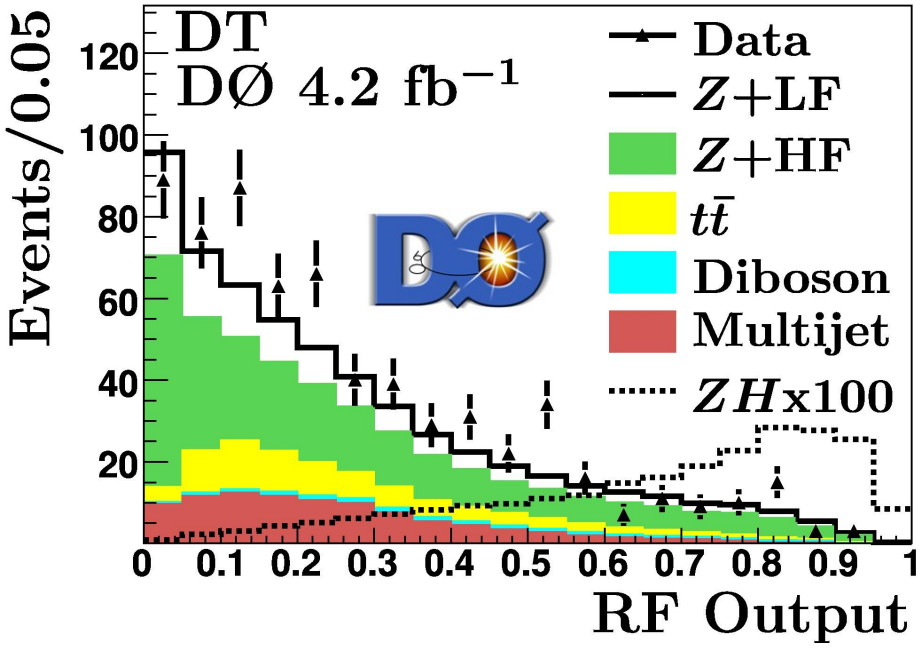
- Two isolated high p_T electrons or muons
- 2 or 3 jets
- b-jet tagging
- Low background, but low signal rate
  - → increase acceptance of lepton reconstruction (15%)
  - → use di-lepton system to constrain di-jet mass (15%)

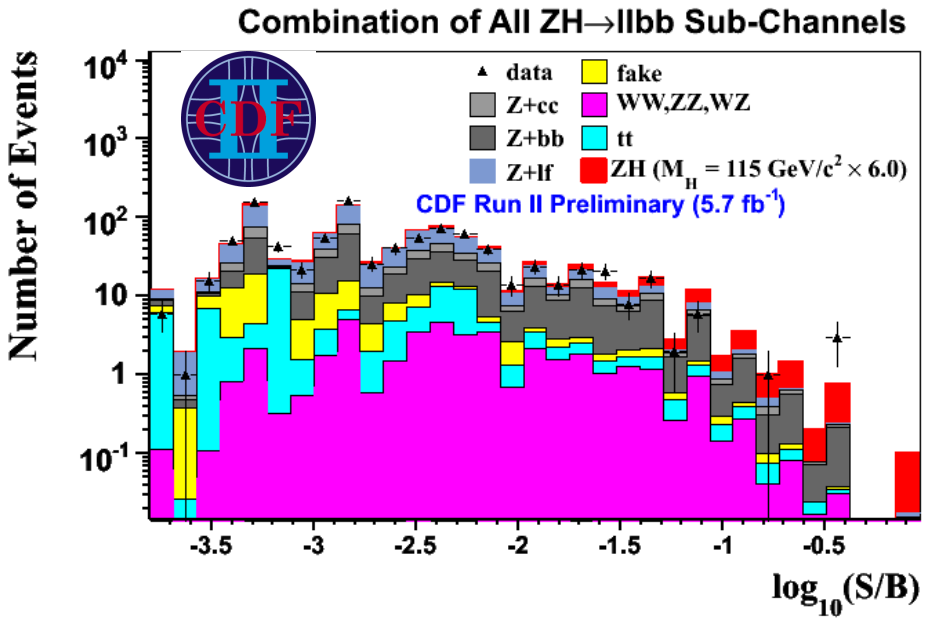


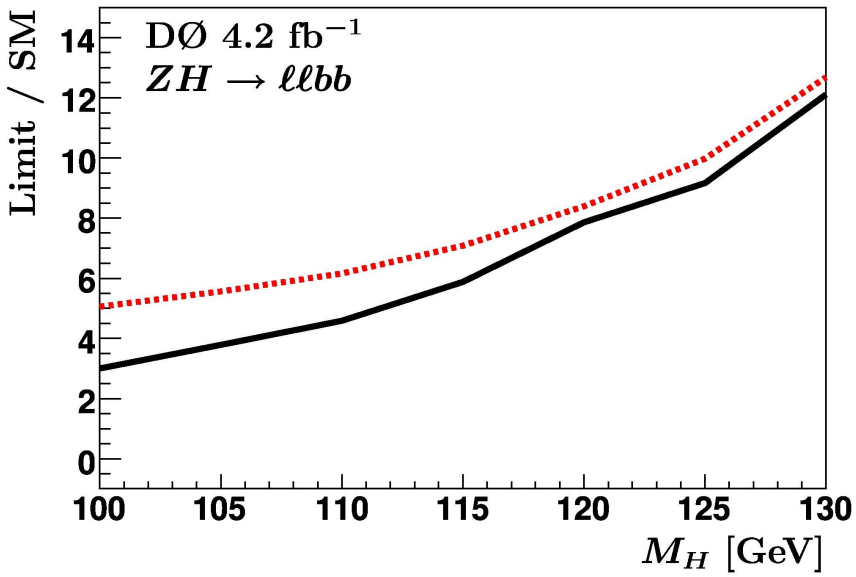
Kinematic Fit

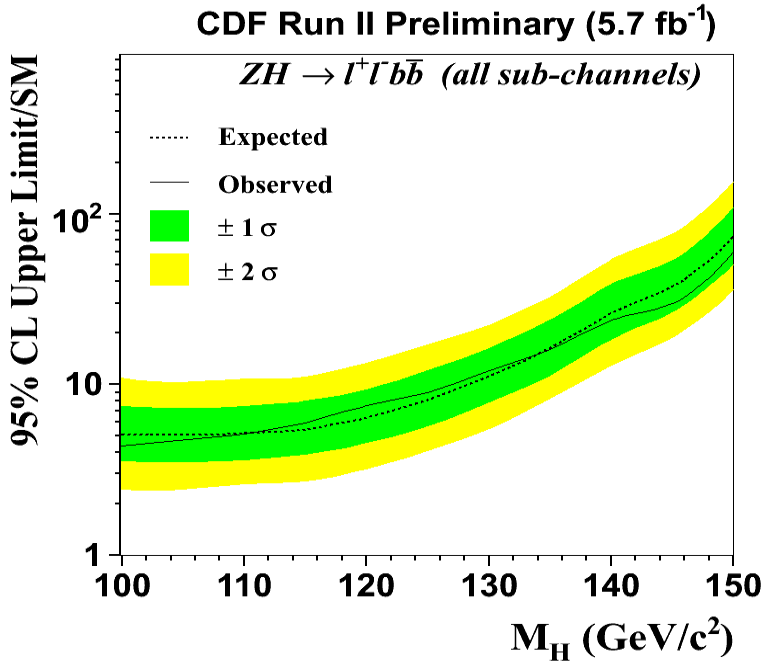


DI-LEPTON + JETS (3)









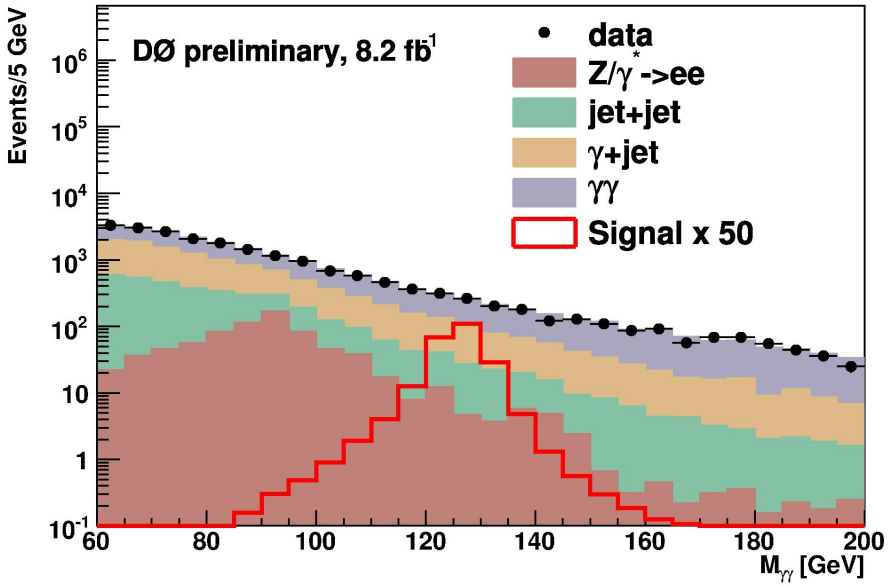
DI-PHOTON

– Two high p_T photons

→ Acceptance increased with forward photons (CDF)

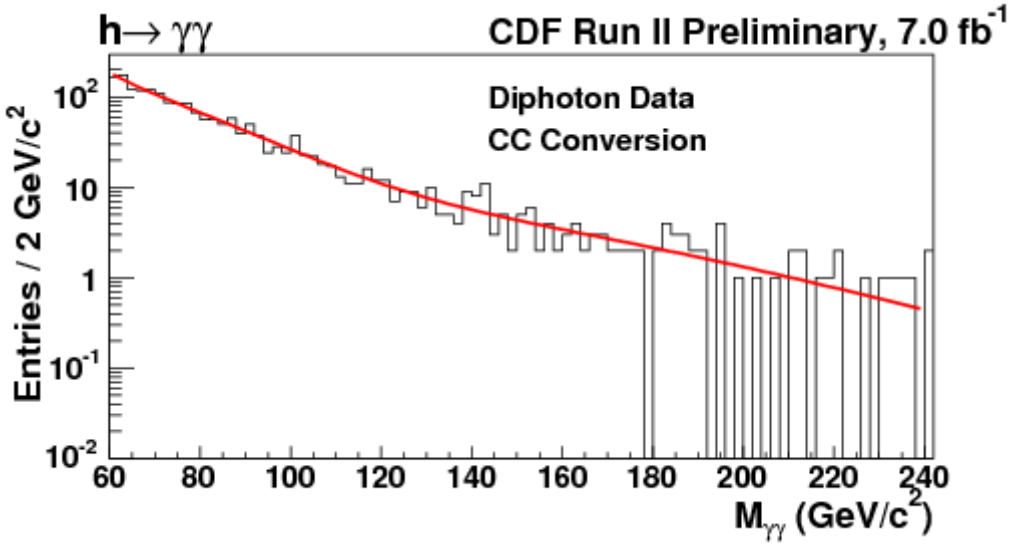
→ Multivariate Analysis (D0)

→ Backgrounds derived from DATA



Observed limit (mH=115 GeV) = 19.9

Expected limit (mH=115 GeV) = 11.0

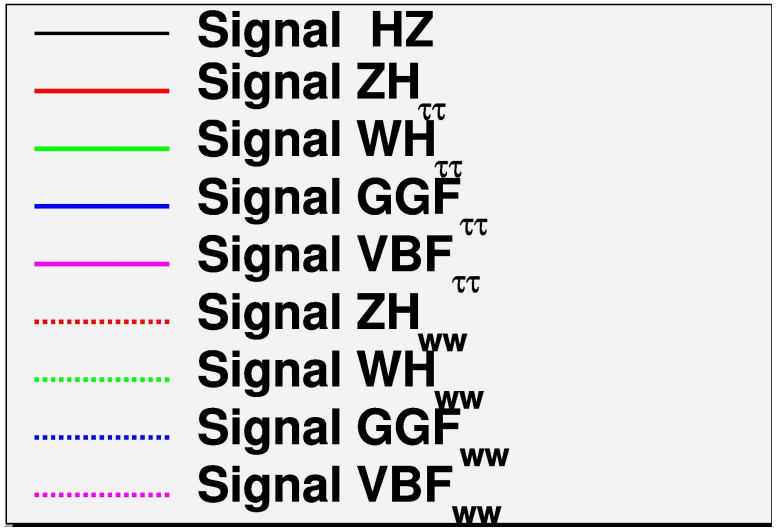


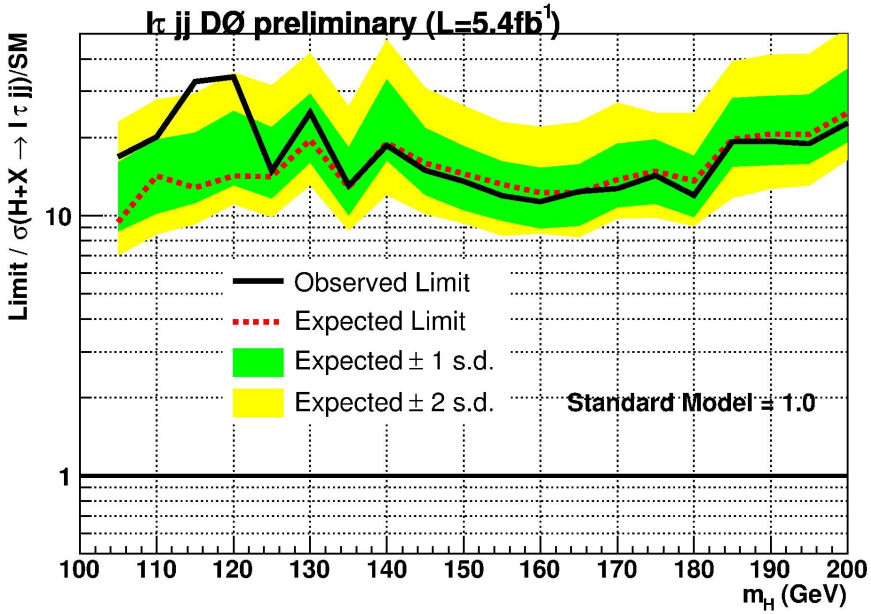
Observed limit (mH=115 GeV) = 14.1

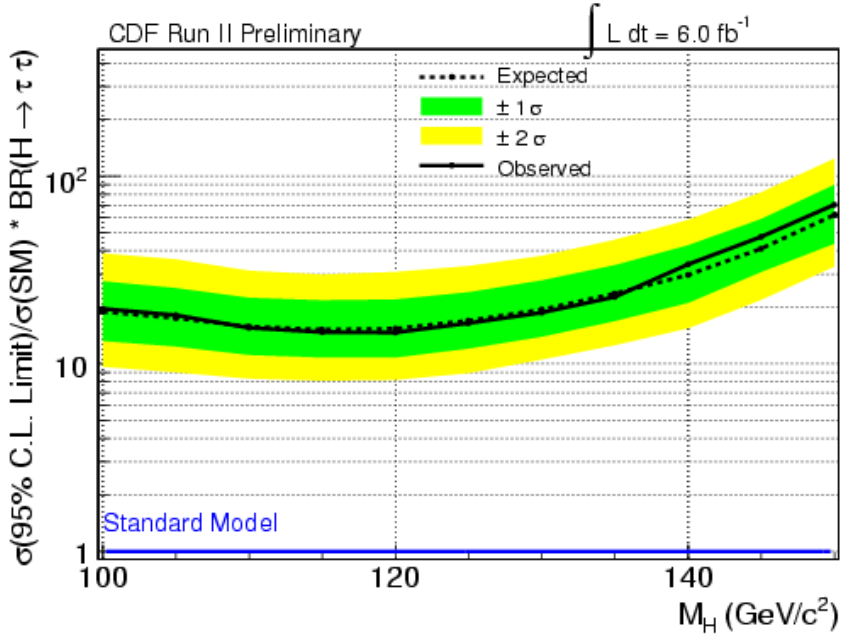
Expected limit (mH=115 GeV) = 13.5

DI-TAU + JETS

- Two high p_T taus: one hadronic and one leptonic
- At least one jet
- Many signals to consider
- Challenging background modeling







COMBINATION

– All analyses are orthogonal → no data overlap

– Correlation of systematics are considered across all input channels
  – theoretical uncertainties are correlated across experiments
  – experimental uncertainties are correlated within experiments
  – ...

– More than **30 channels** per experiment
– Shape is used

– Two methods are used:
  – Bayesian Method (CDF)

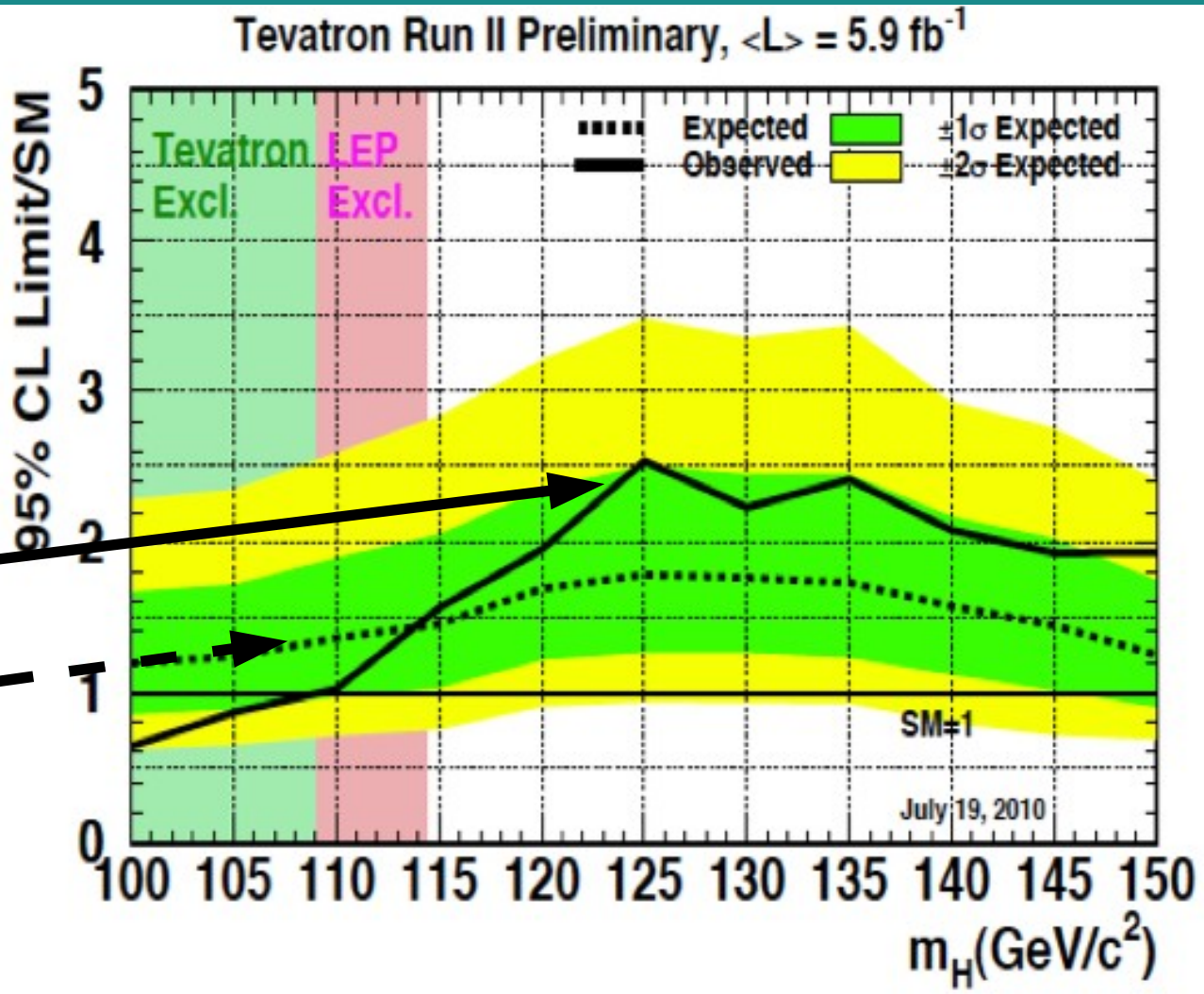
$$\mathcal{L}(R,\vec{s},\vec{b}|\vec{n},\vec{\theta})\times\pi(\vec{\theta}) = \prod_{i=1}^{N_C}\prod_{j=1}^{Nbins}\mu_{ij}^{n_{ij}}e^{-\mu_{ij}}/n_{ij}!\times\prod_{k=1}^{n_{np}}e^{-\theta_k^2/2}$$

  – Modified frequentist method (DØ)

$$LLR = -2\ln\frac{p(\text{data}|H_1)}{p(\text{data}|H_0)} \qquad CL_s = CL_{s+b}/CL_b$$

– Both methods agree within 10% → Good crosscheck.

COMBINED EXCLUSION LIMITS



DATA

EXPECTED BKG ONLY

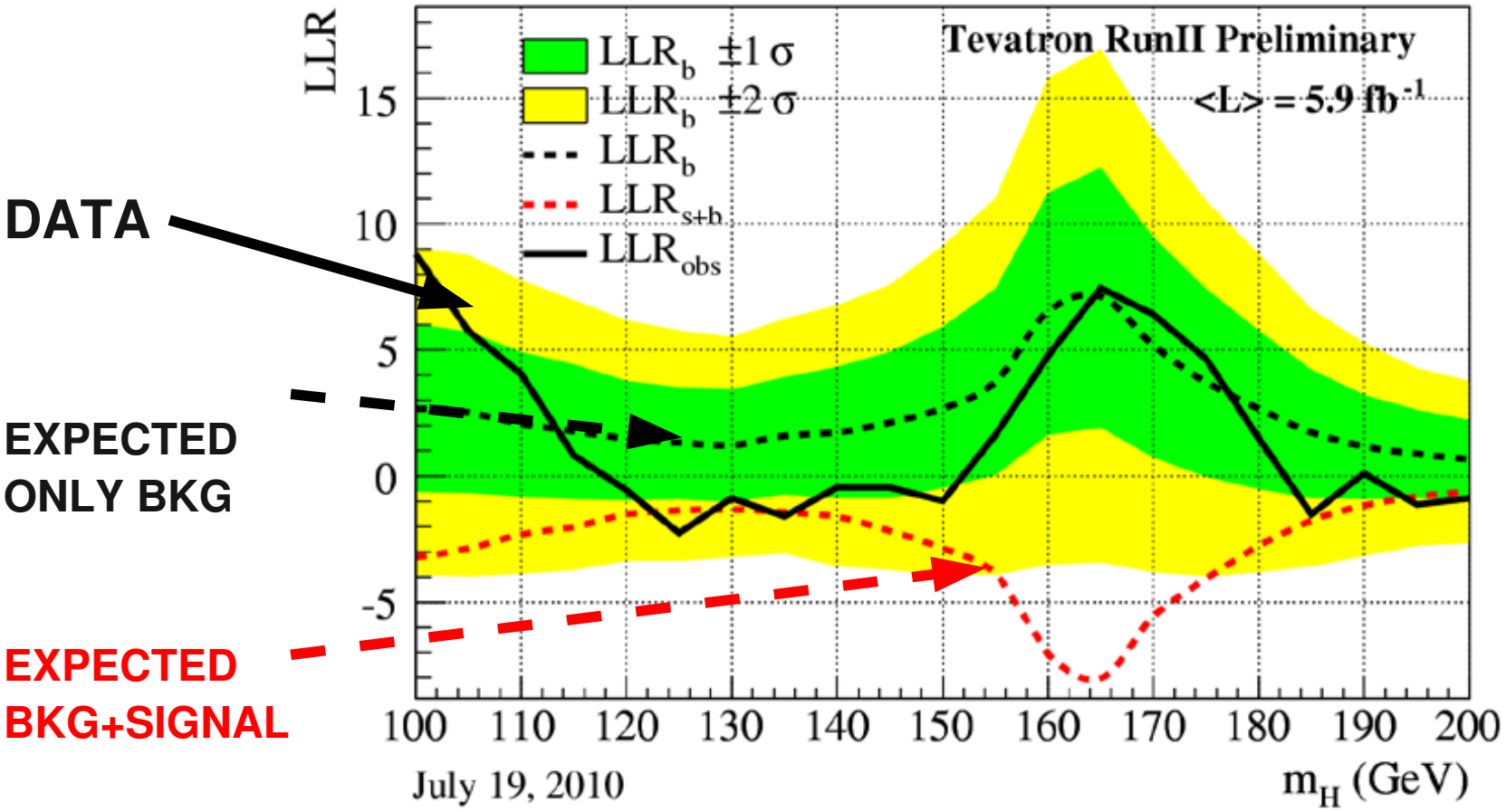
Bayesian	100	105	110	115	120	125	130	135	140	145	150
Expected	1.20	1.24	1.36	1.45	1.69	1.78	1.76	1.73	1.57	1.45	1.25
Observed	0.64	0.87	1.02	1.56	1.95	2.54	2.23	2.41	2.07	1.92	1.93

CL_s	100	105	110	115	120	125	130	135	140	145	150
Expected	1.17	1.24	1.36	1.50	1.66	1.73	1.78	1.69	1.56	1.39	1.20
Observed	0.61	0.86	1.06	1.64	2.05	2.72	2.38	2.53	2.07	1.90	1.79

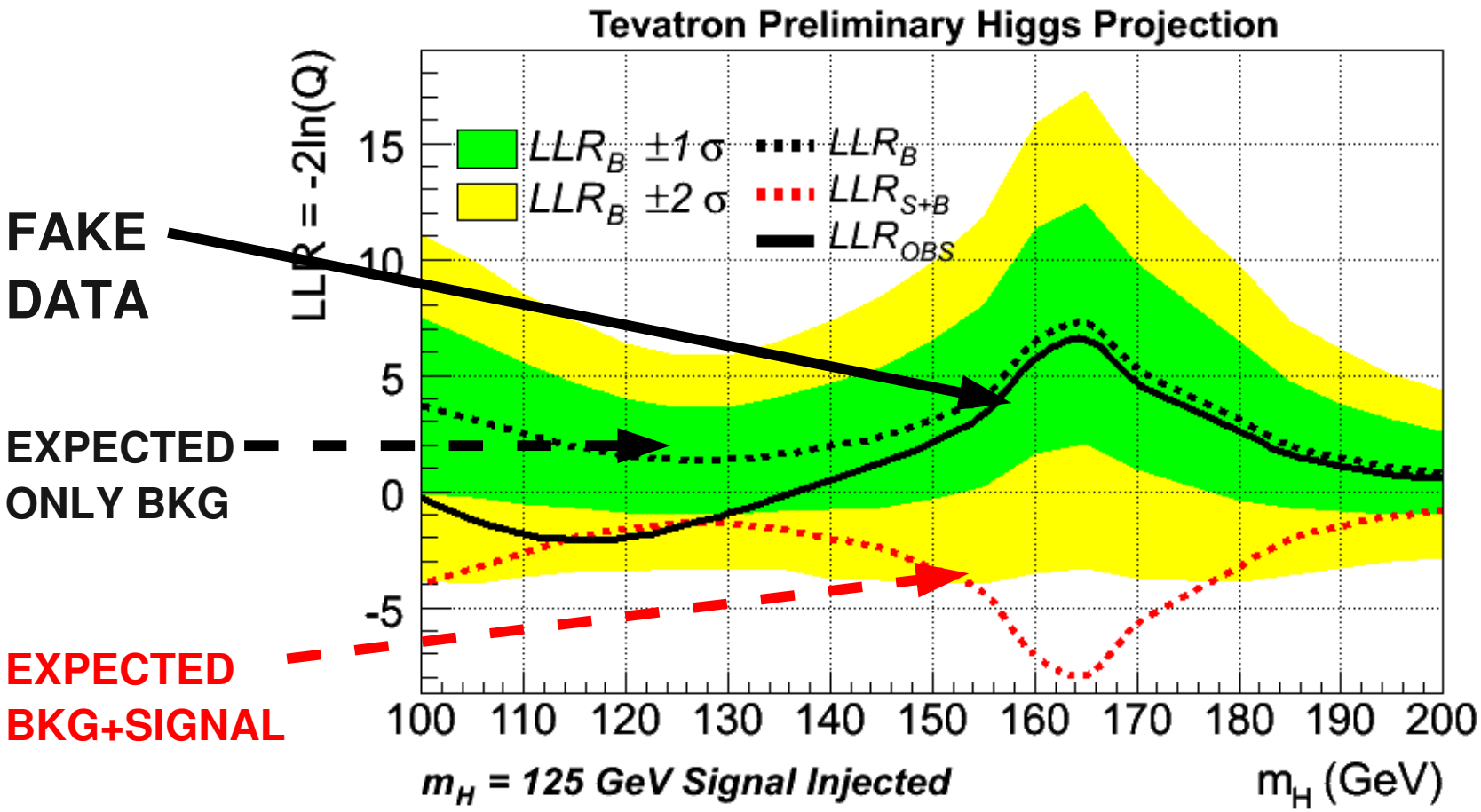
SIGNAL INJECTION

What would a Higgs signal look like?

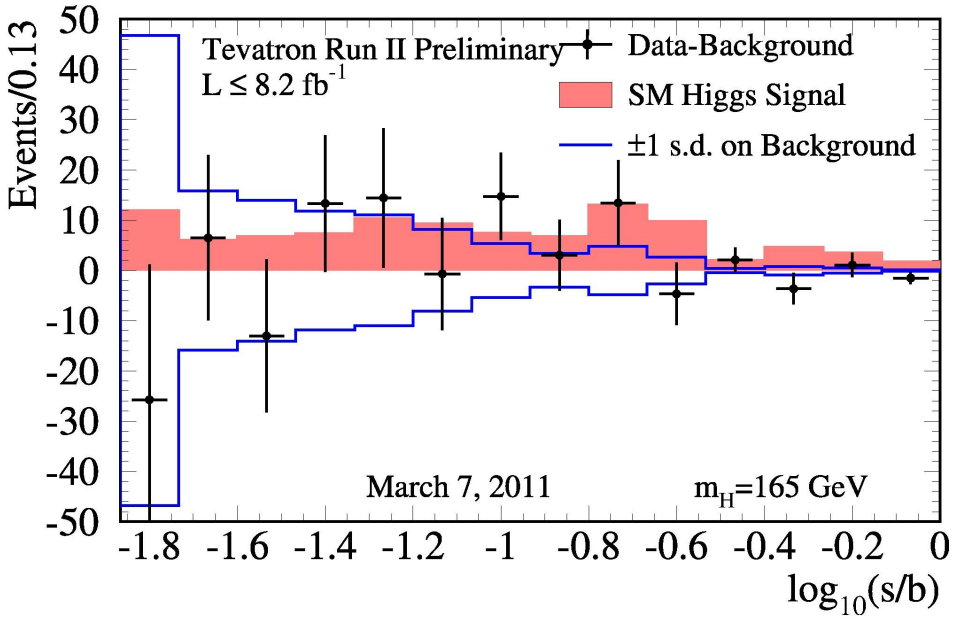
→ One can inject a signal in the limits calculation

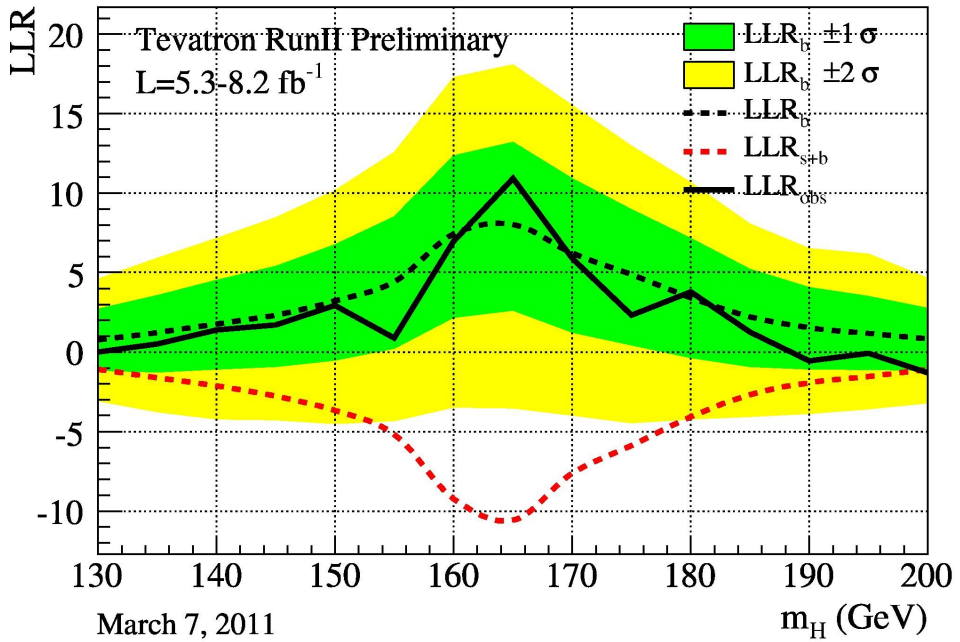


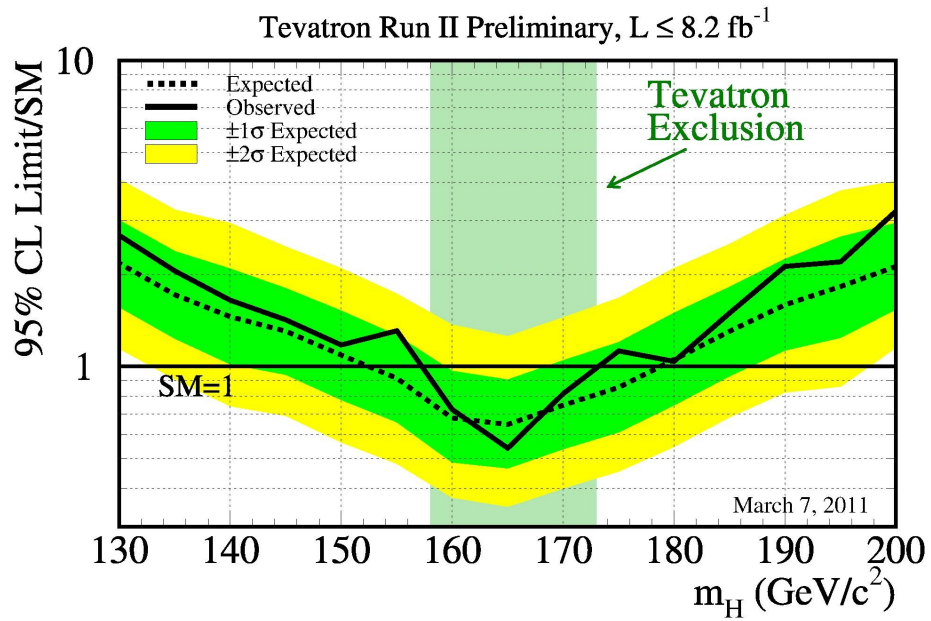
SIGNAL INJECTION



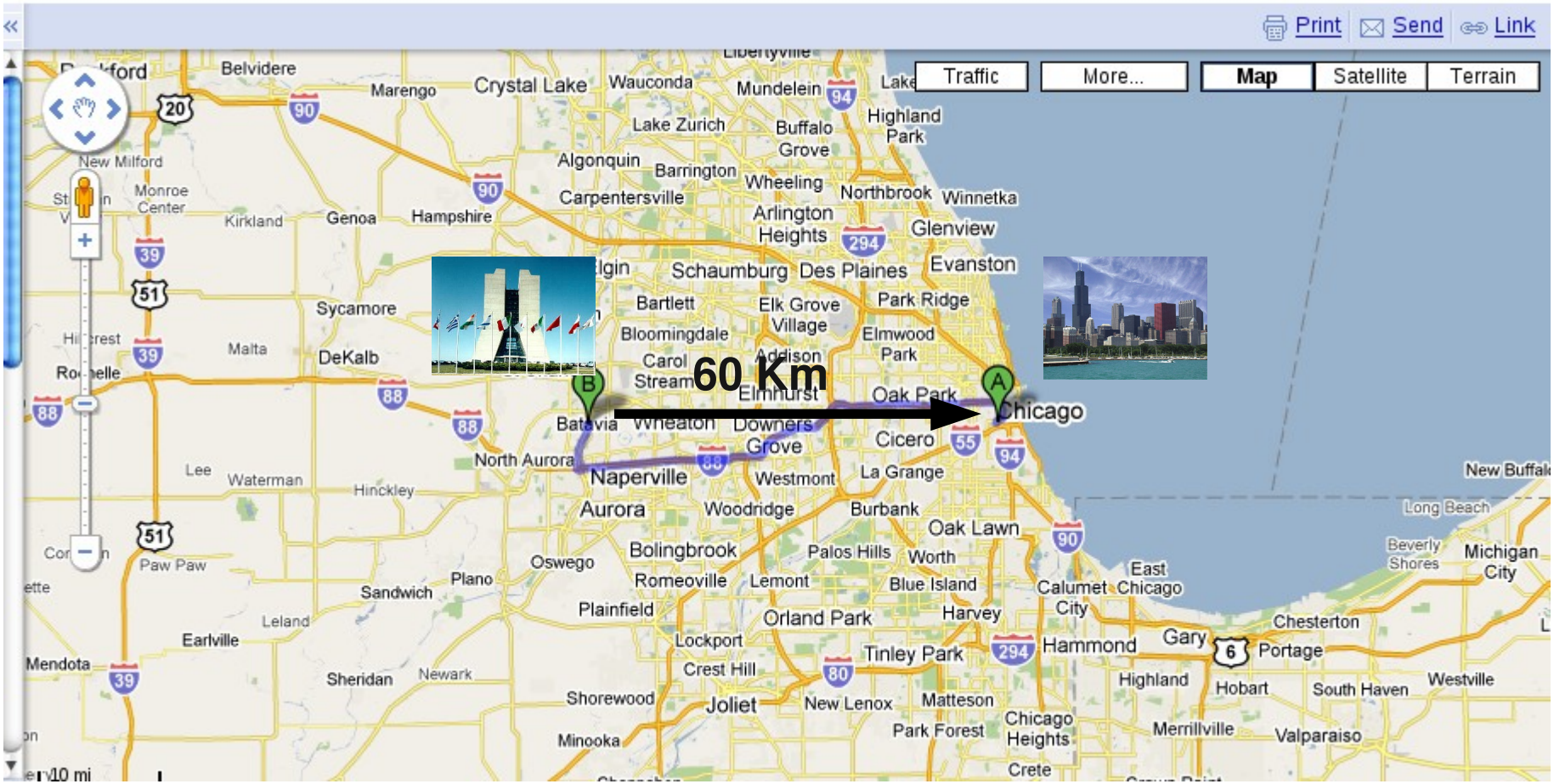
FEW WORDS ABOUT HIGH MASS



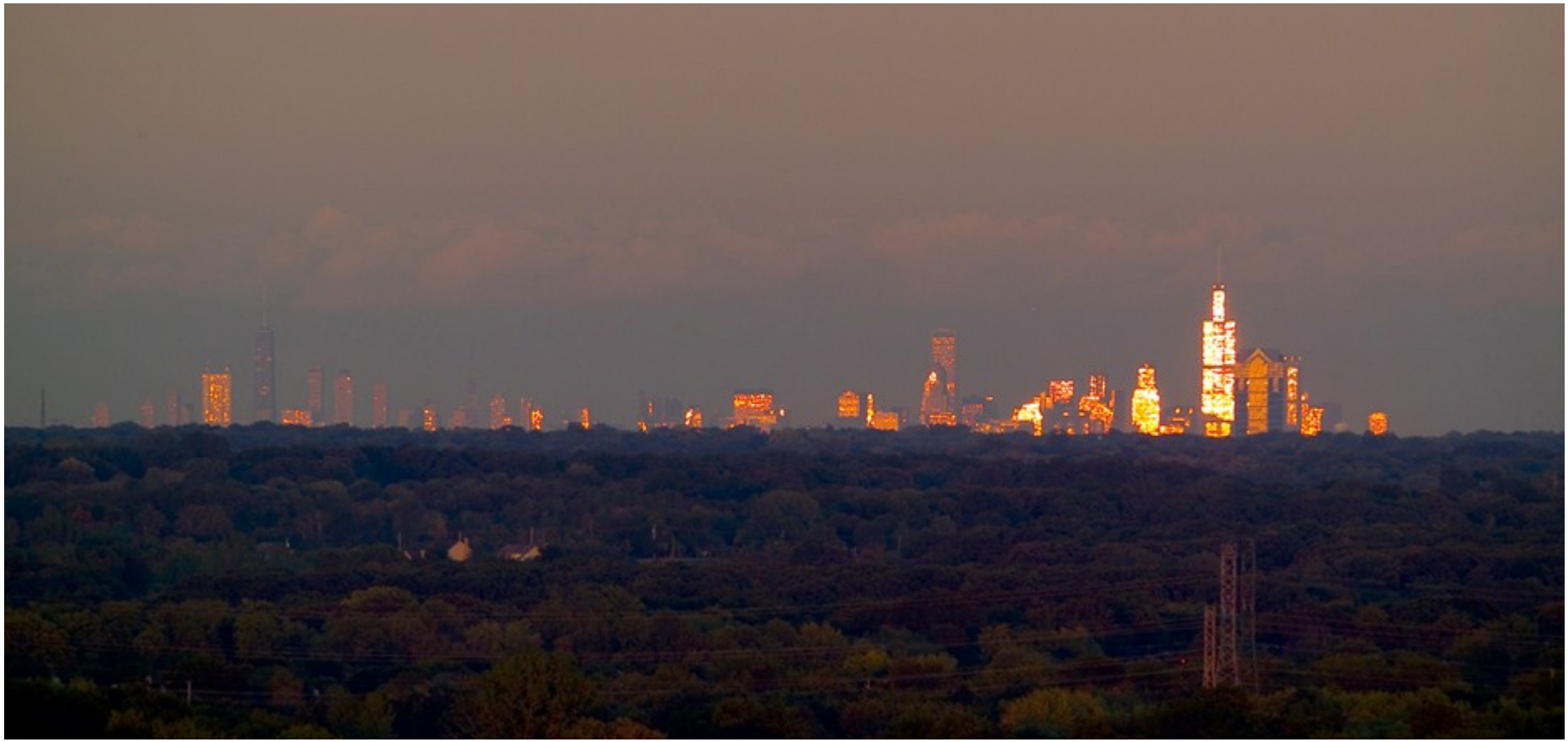




CAN WE SEE CHICAGO SKY LINE FROM FERMILAB?



YES,



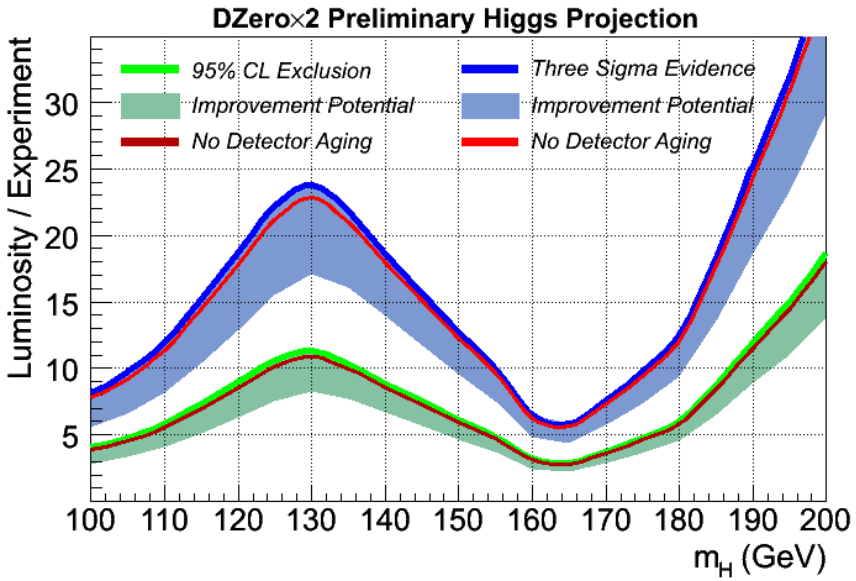
SUMMARY

– Higgs searches are rapidly improving at Tevatron

→ Excellent Tevatron performance

→ Great detectors operation, algorithm and analysis improvements

– With 12/fb, we expect to be sensitive for the SM Higgs over the entire mass range



– A Tevatron combination update is expected for Summer 11.

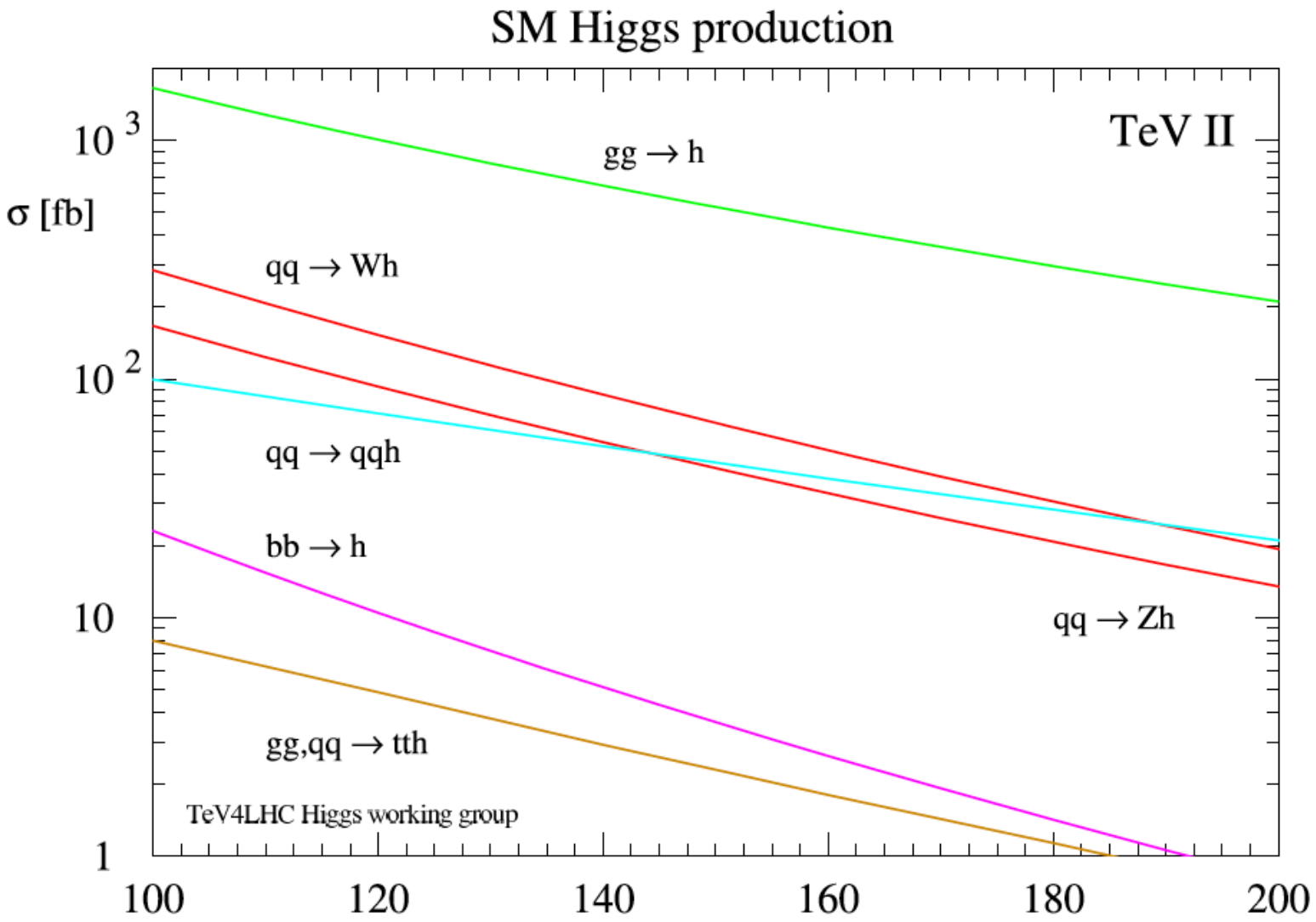
For more details, see:

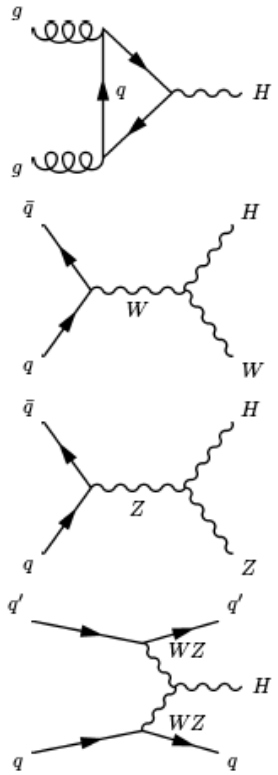
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

http://www-cdf.fnal.gov/physics/new/hdg/hdg.html

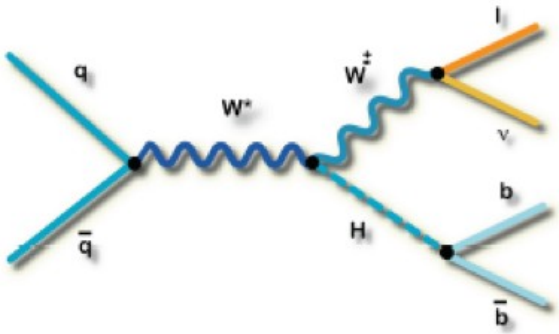
BACKUP

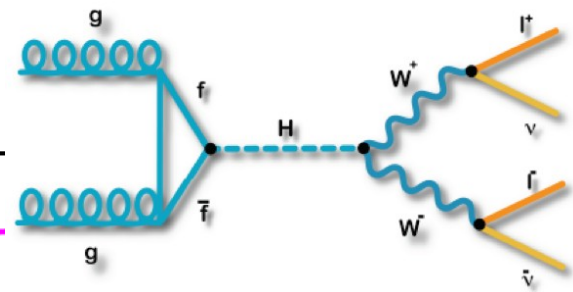
HIGGS PRODUCTION AT THE TEVATRON

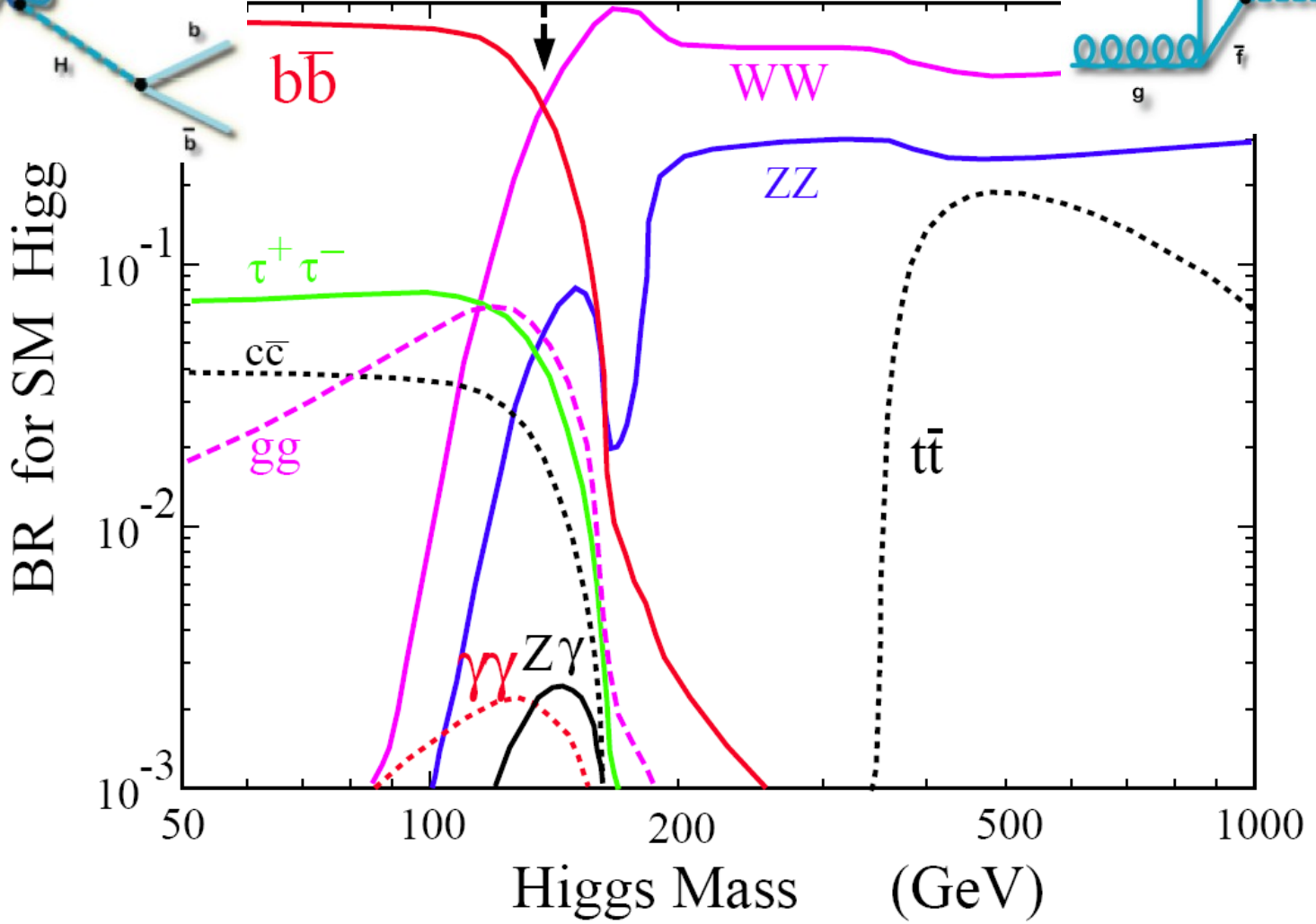




HIGGS DECAYS



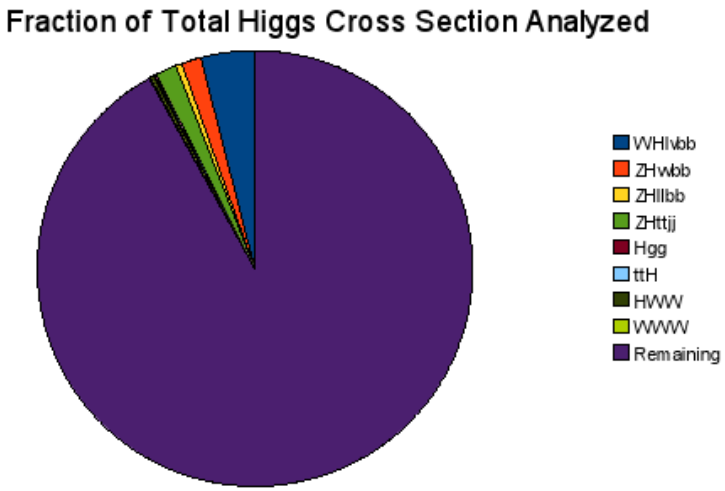


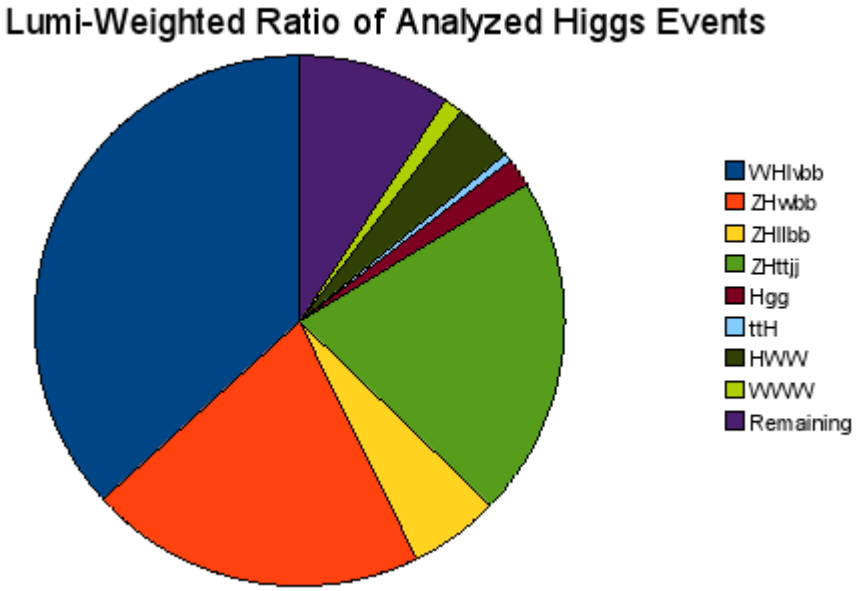


Most sensitive channels are the associate production V+H(→bb) at low mass and gluon fusion H(→WW) at high mass.

SEARCH STRATEGY

Most of Higgs production do not provide sizable sensitivity ...





… but from the achievable analysis, most of them are covered.

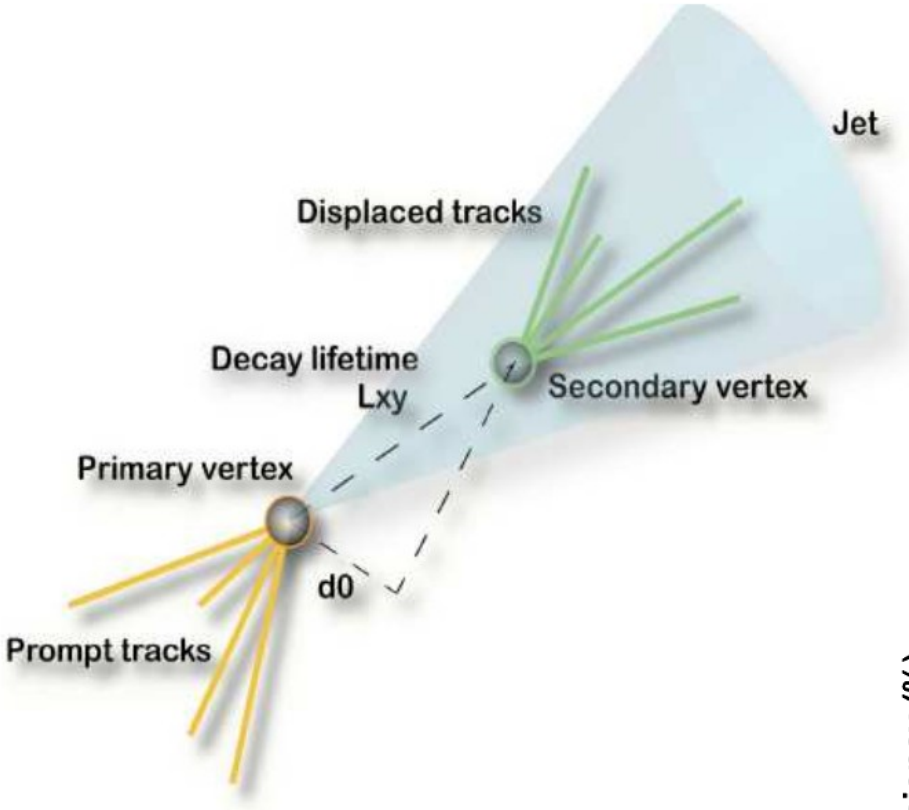
SIGNAL AND BACKGROUND MODELING

Signal and “SM” backgrounds are predicted by simulation corrected to the best knowledge of theoretical cross sections.

QCD or Multijet is predicted by data driven methods looking at regions where this background is expected to dominate.

Control samples are largely used to validate background modeling.

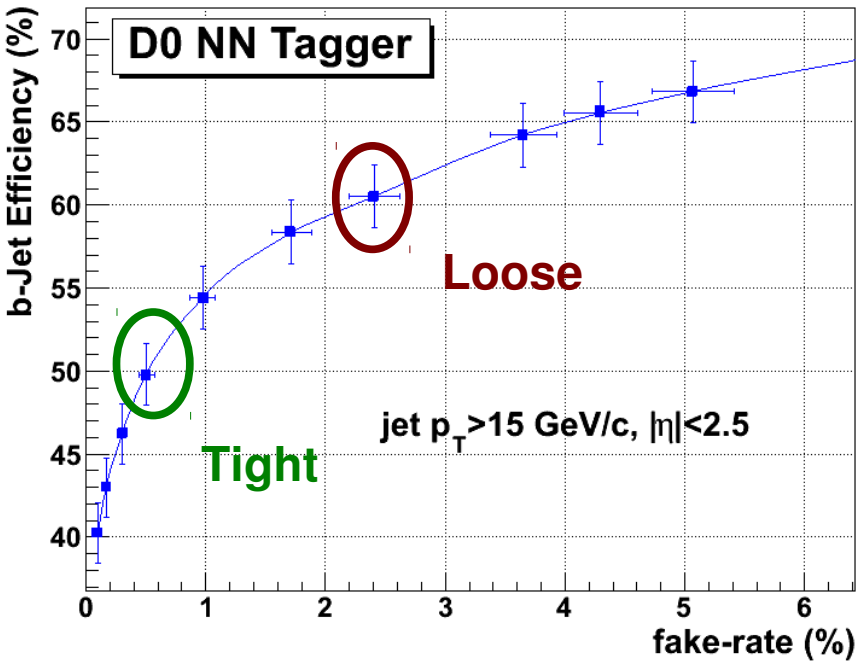
B-TAGGING



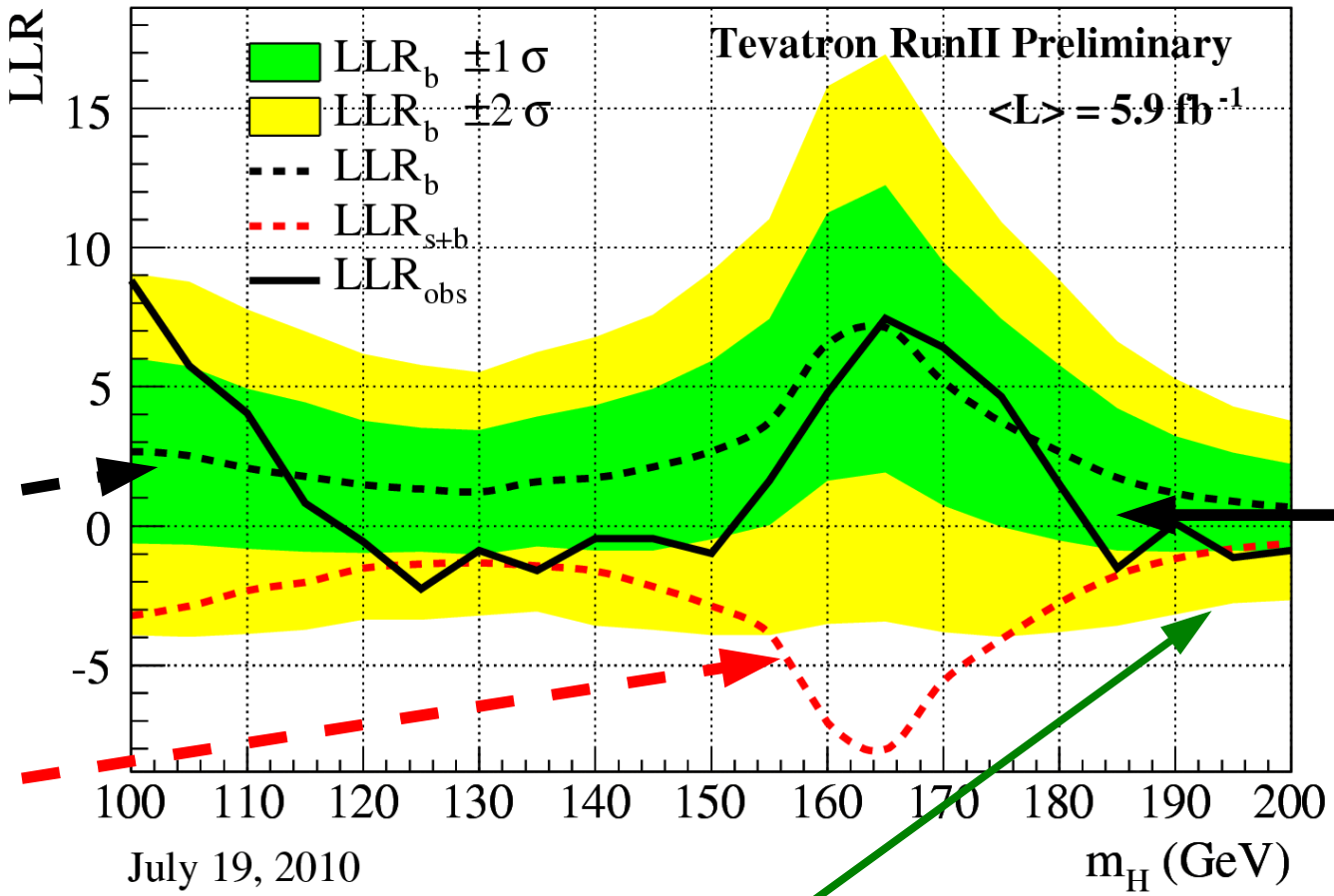
Differences between b-jets and light-jets are used to suppress light flavor backgrounds:

- secondary vertex
- track impact parameters
- vertex track multiplicity
- vertex mass
- soft leptons

Multivariate analysis is used to optimize discrimination.



LLR



EXPECTED ONLY BKG

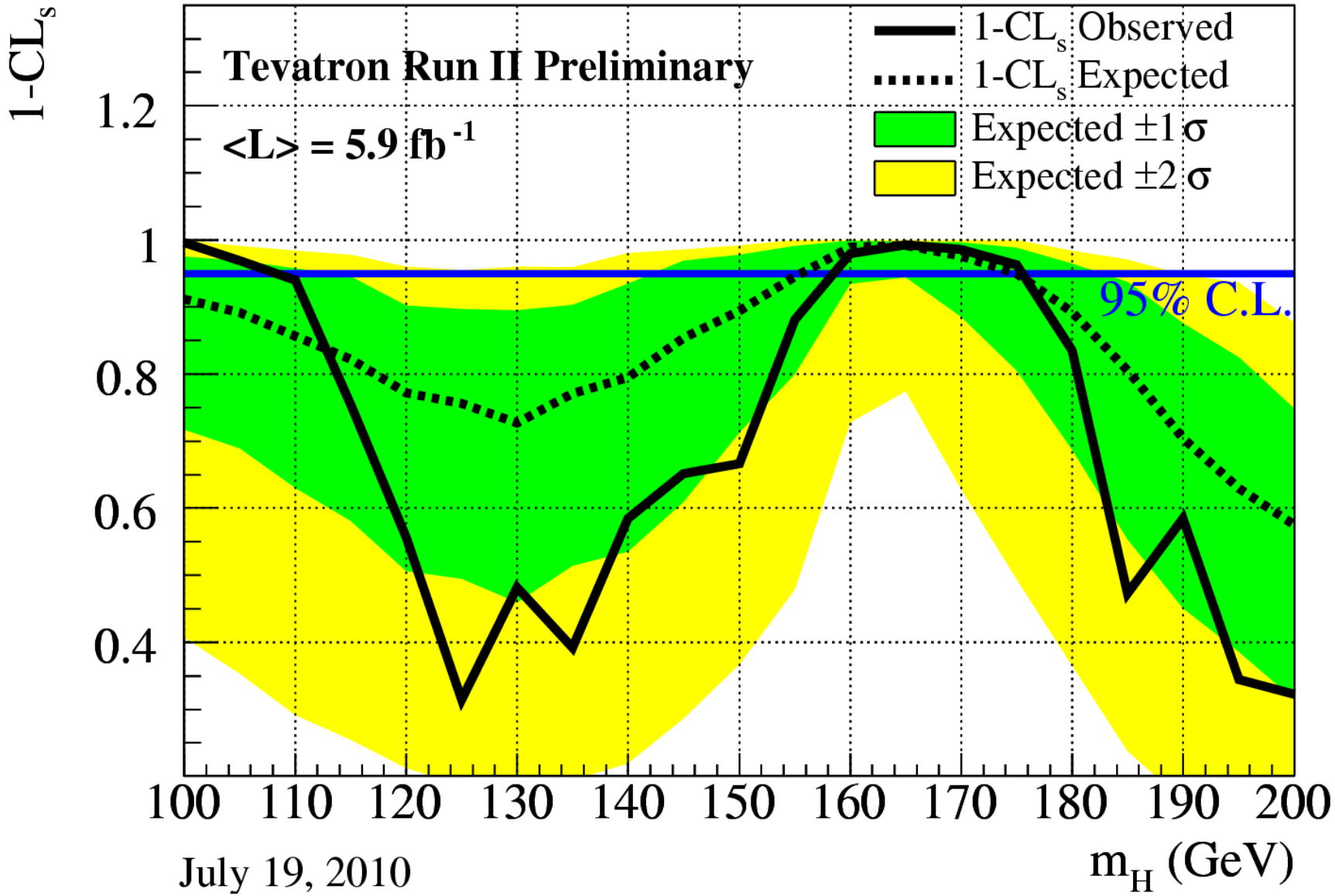
EXPECTED BKG+SIGNAL

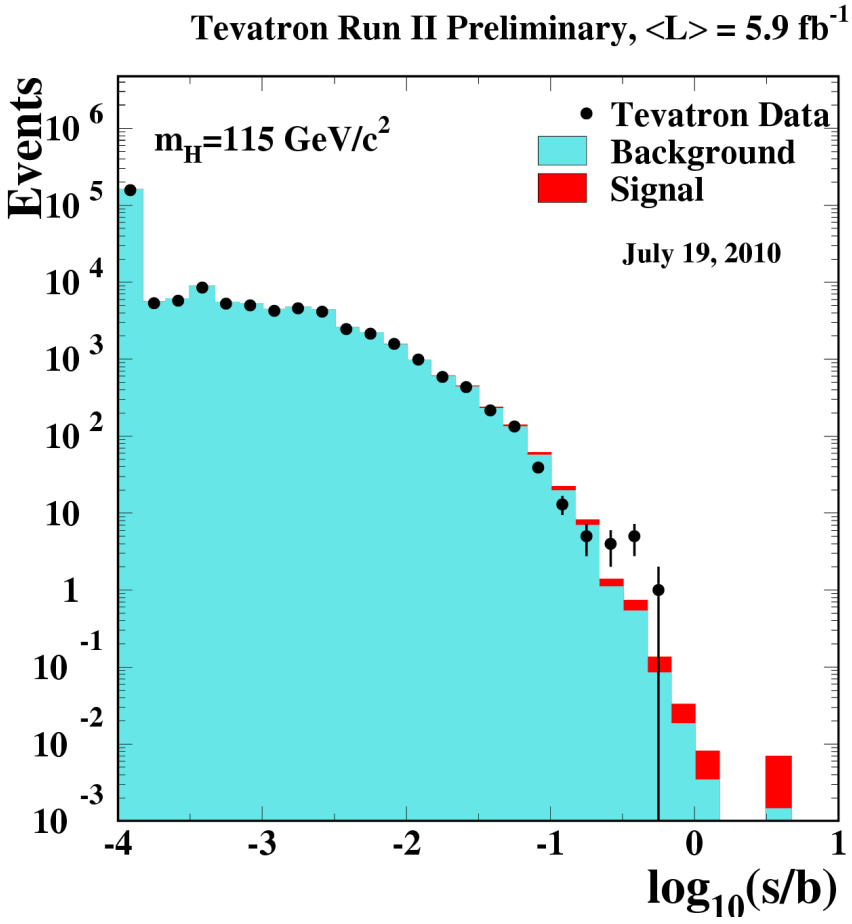
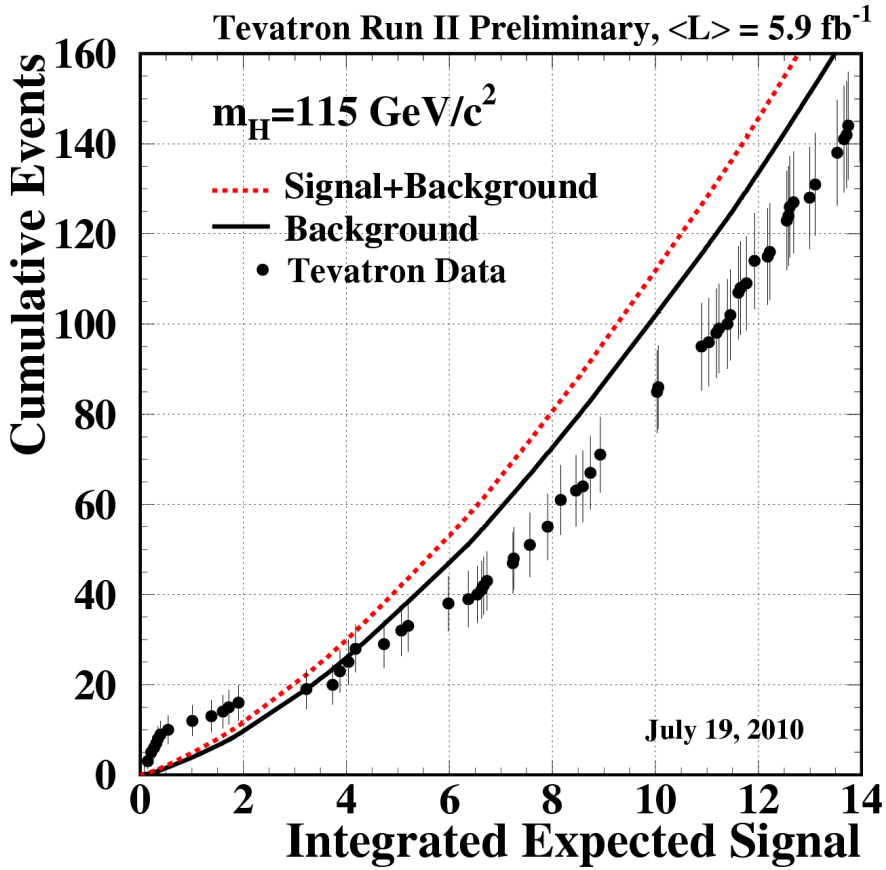
DATA

1 (2) σ in green (yellow) from background only expectation.

1-CLs

1-CLs = confidence level of the exclusion



REBINNED INPUTS (m_H = 115 GeV)

Limit calculation is sensitive to log(s/b)
Reorder bins according to this variable.