URA thesis award 2011: (Not-so) High mass Higgs searches at the CDF experiment

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For work done with:

INFN and University of Padova

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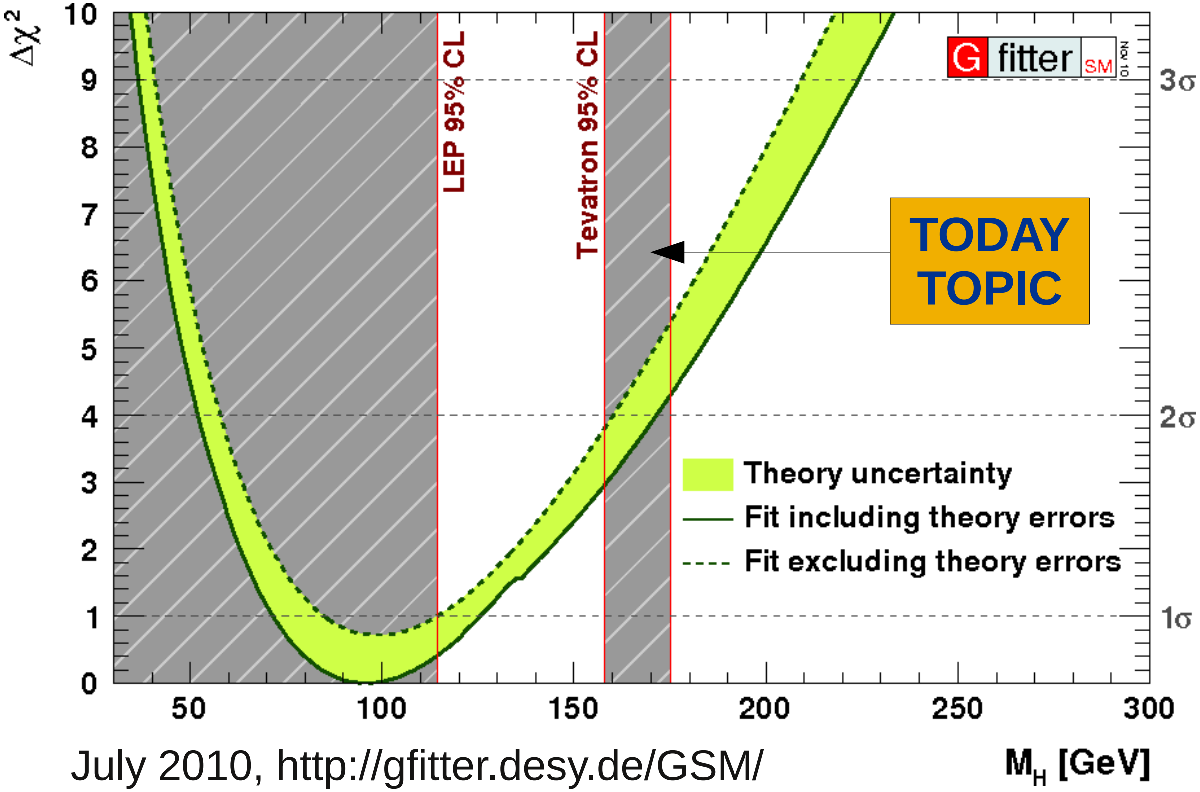
Higgs boson: state of the art

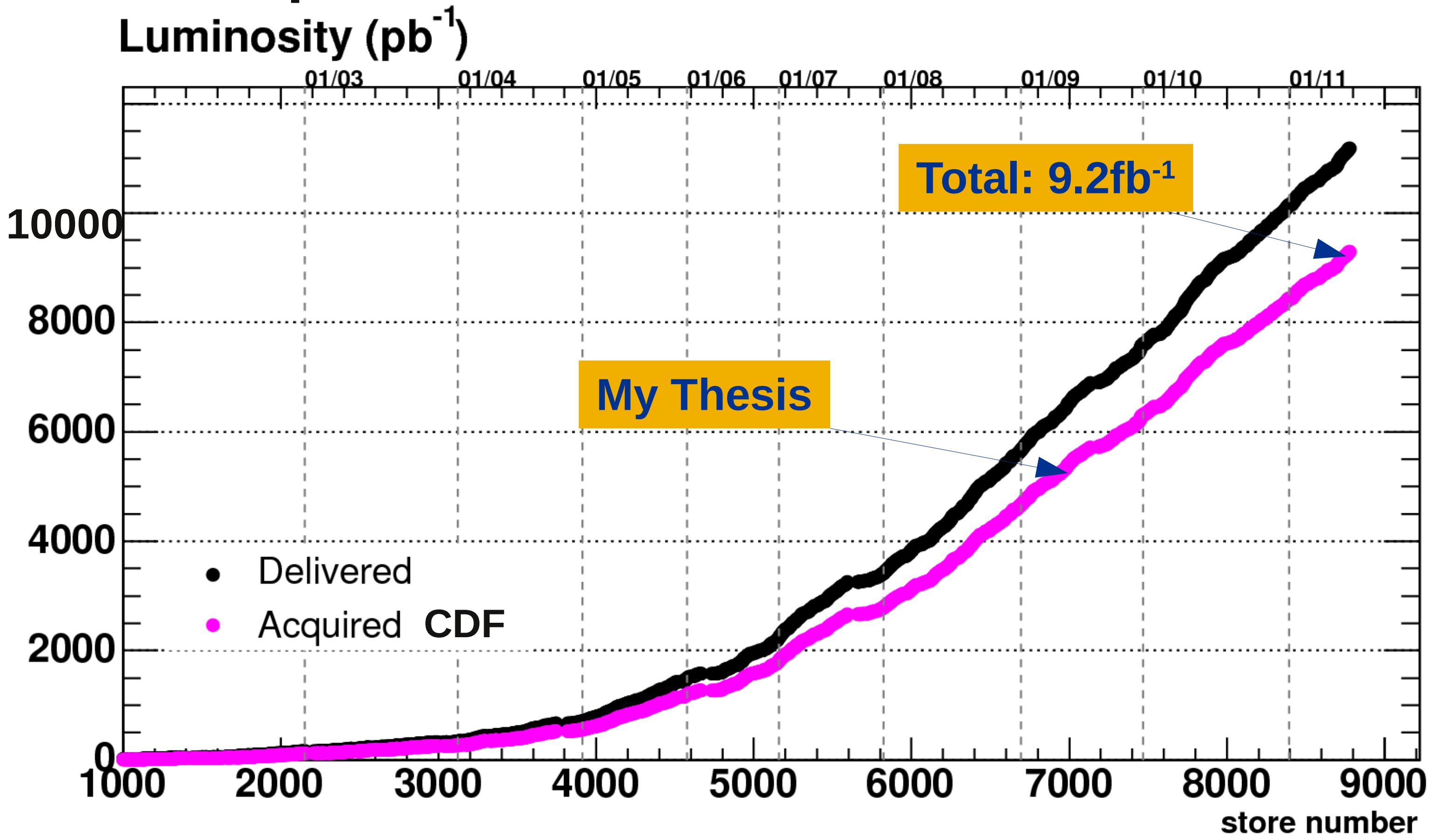
- **Indirect constraints from SM observables**
  - Depend on Higgs mass through radiative corrections
- **Direct searches at LEP and Tevatron**



July 2010, http://gfitter.desy.de/GSM/

Tevatron collider

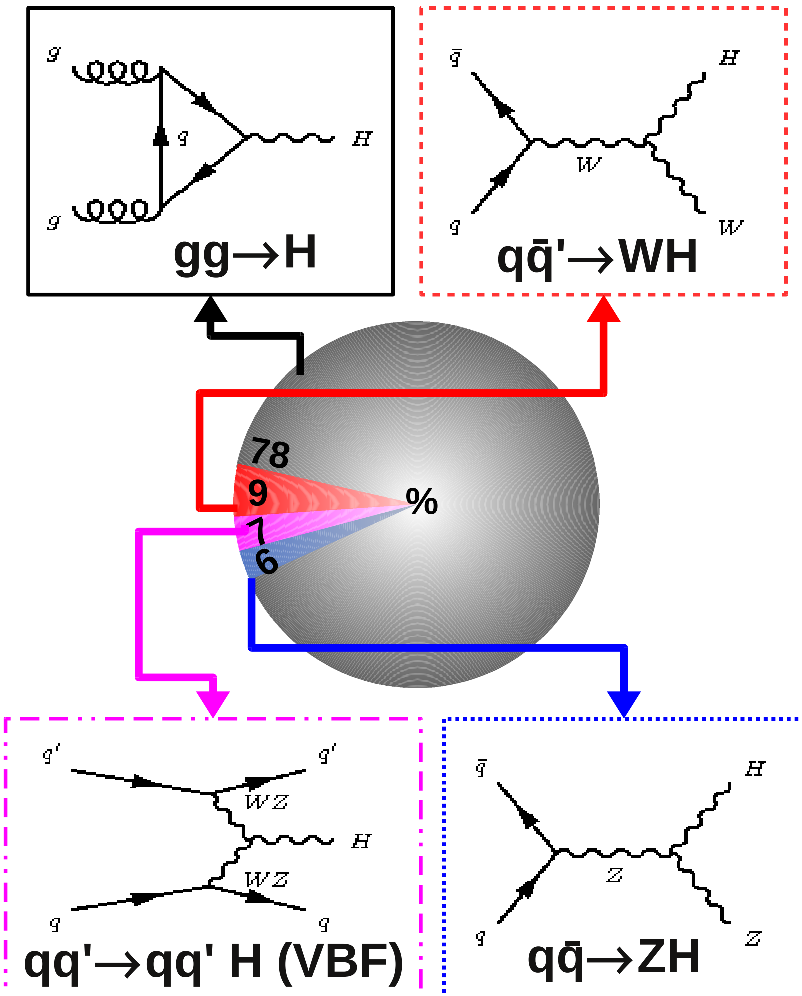
- **Proton-antiproton collisions at $\sqrt{s}$ = 1.96 TeV**

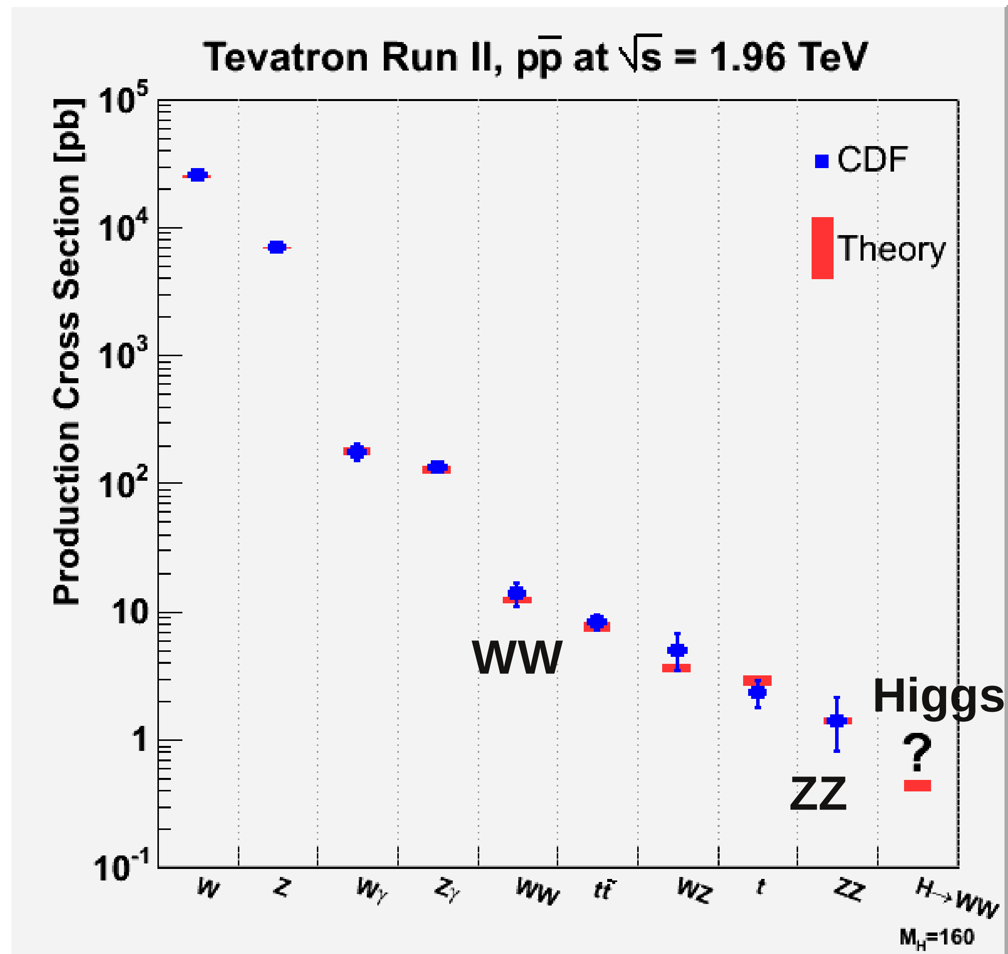


- **Excellent Tevatron performance: $L^{inst} > 4 \cdot 10^{32} cm^{-2} s^{-1}$**
- **CDF detector ~83% efficiency in recording data**

Higgs production

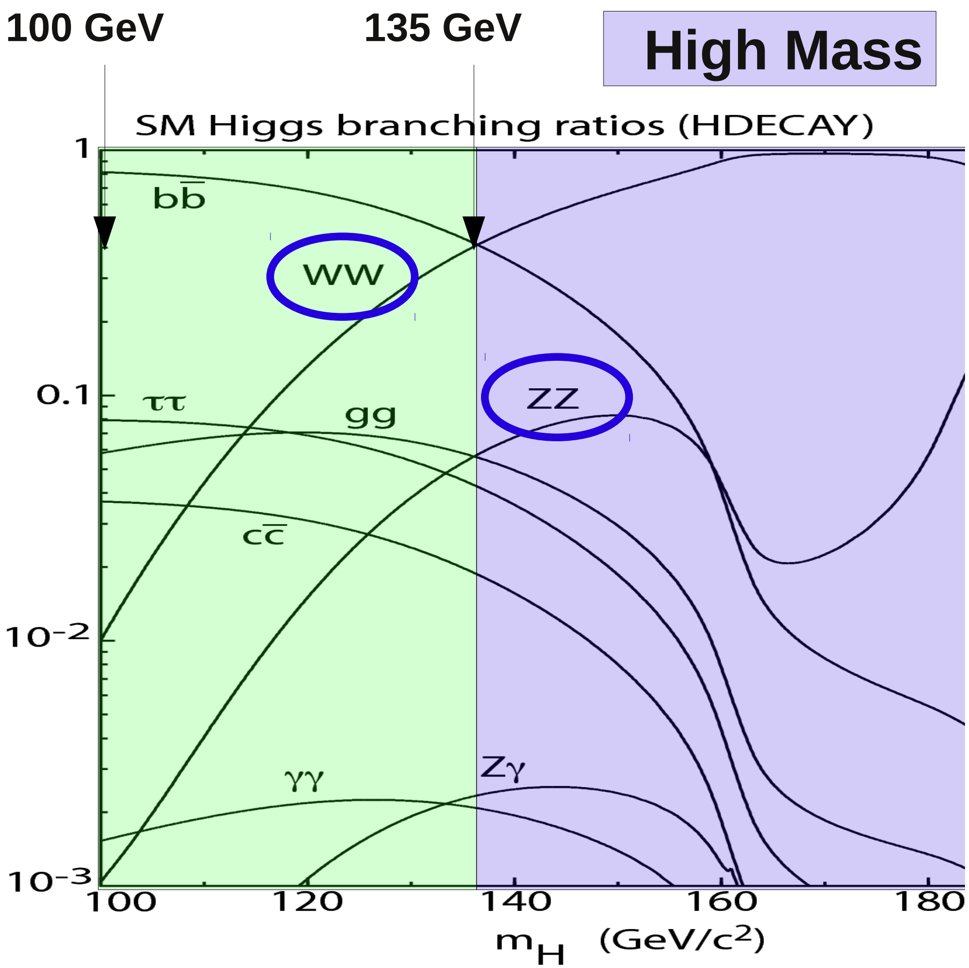
- **Total cross section 0.2 – 1.5 pb (m_H = 110 - 200 GeV)**

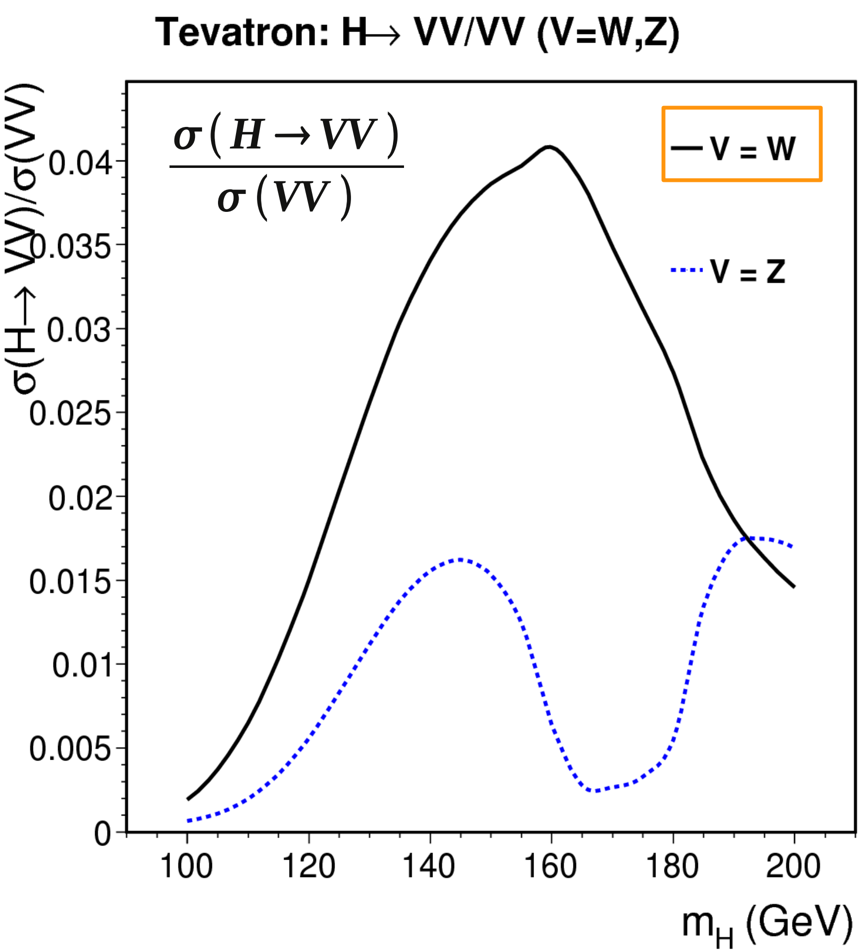




Higgs decay

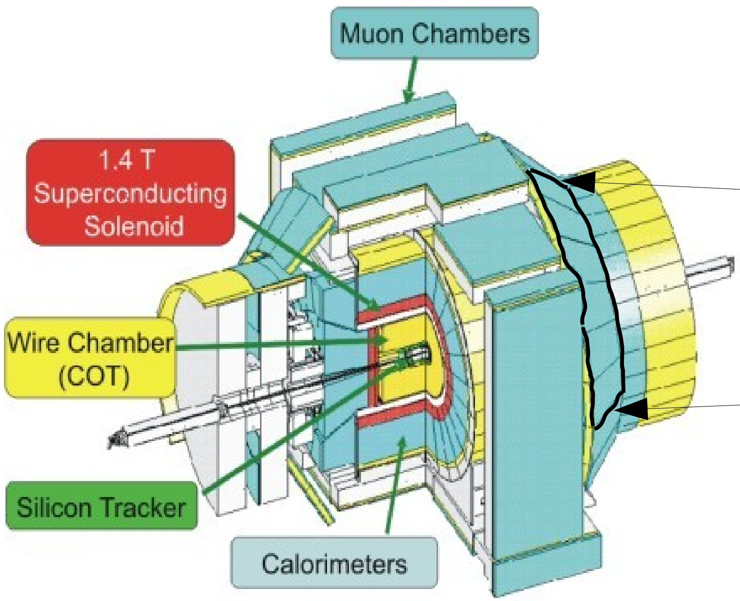
- **For m_H > 135 GeV, H → WW dominant decay channel**

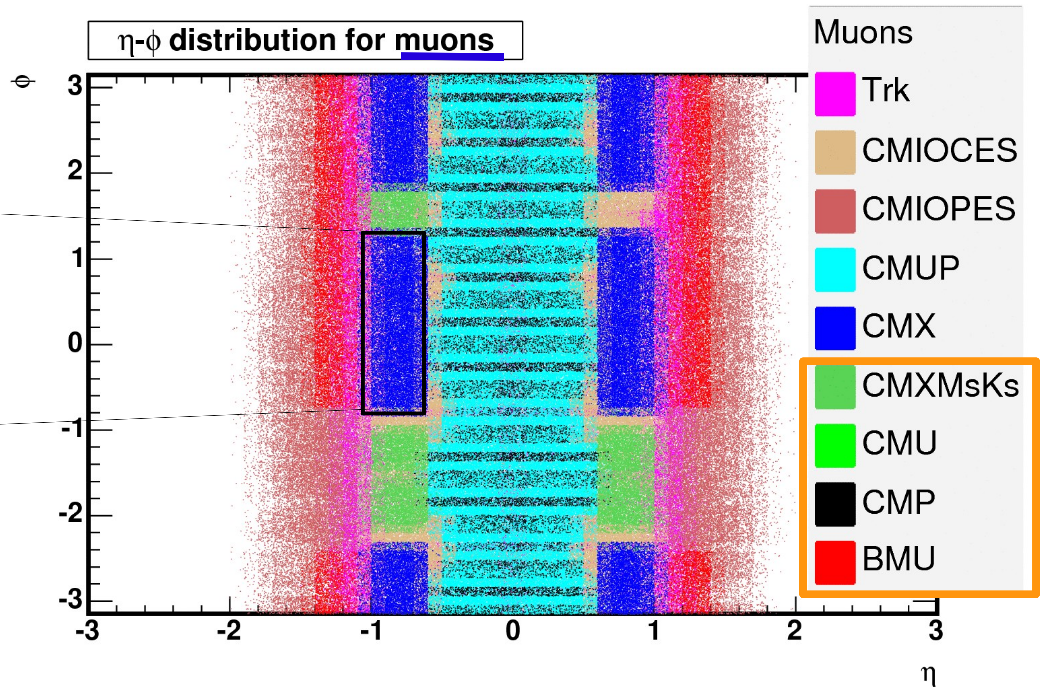




Lepton acceptance @ CDF

- **We select both Ws decaying leptonically: e,μ (BR ~ 6%)**
  - Hadronic W,Z decays suffer large QCD background

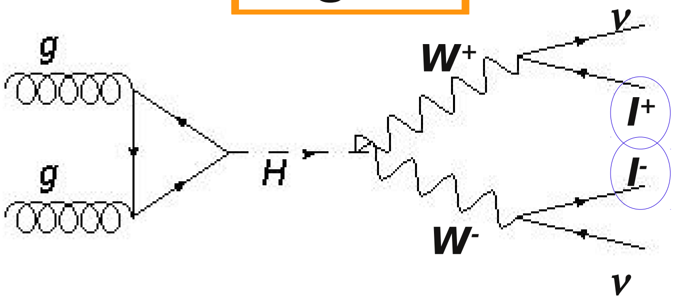




- **Increase lepton ($e^{\pm}$ and $\mu^{\pm}$) acceptance at the most**
  - increase trigger leptons (cover holes by inter-play b/w subdetectors)
  - More sophisticated lepton identification algorithms

H → WW signature: direct production

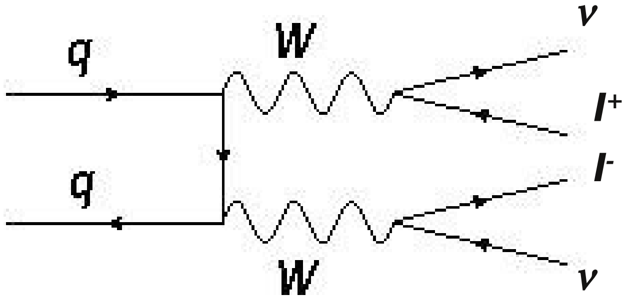
Signal



H Direct Production at Leading Order

- **Two Opposite sign leptons**
- **0 jets**
- **Missing transverse Energy (ν)**

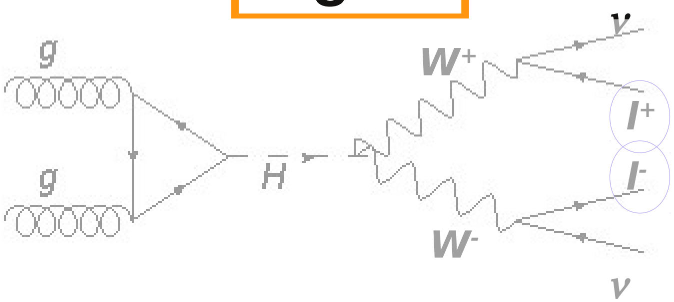
Background



WW non resonant

H → WW: associated production

Signal



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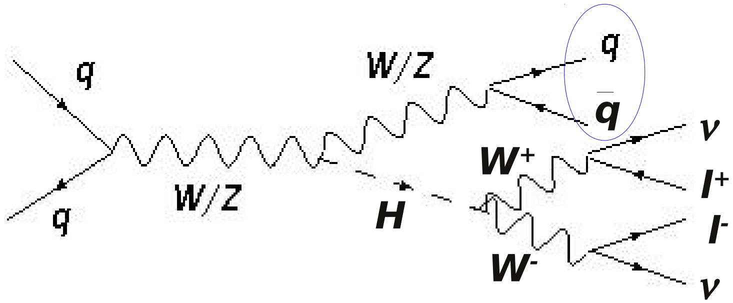
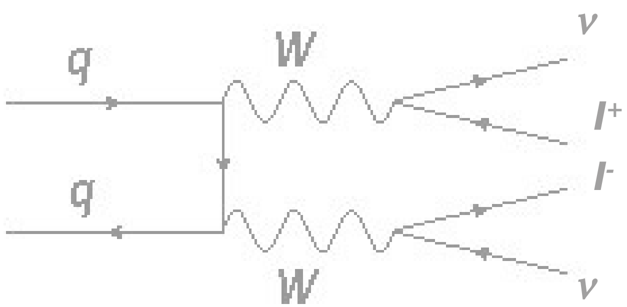
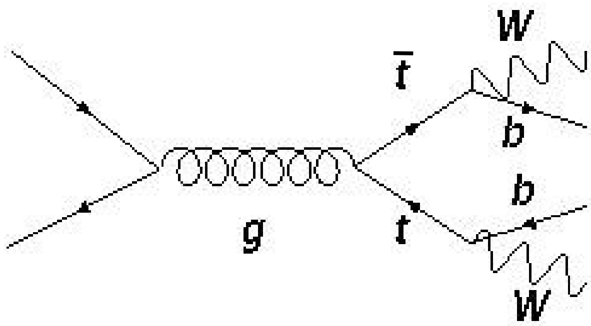


- **2 Opposite Sign leptons**
- **2 jets** at LO
- **Missing Tranverse Energy**

Background



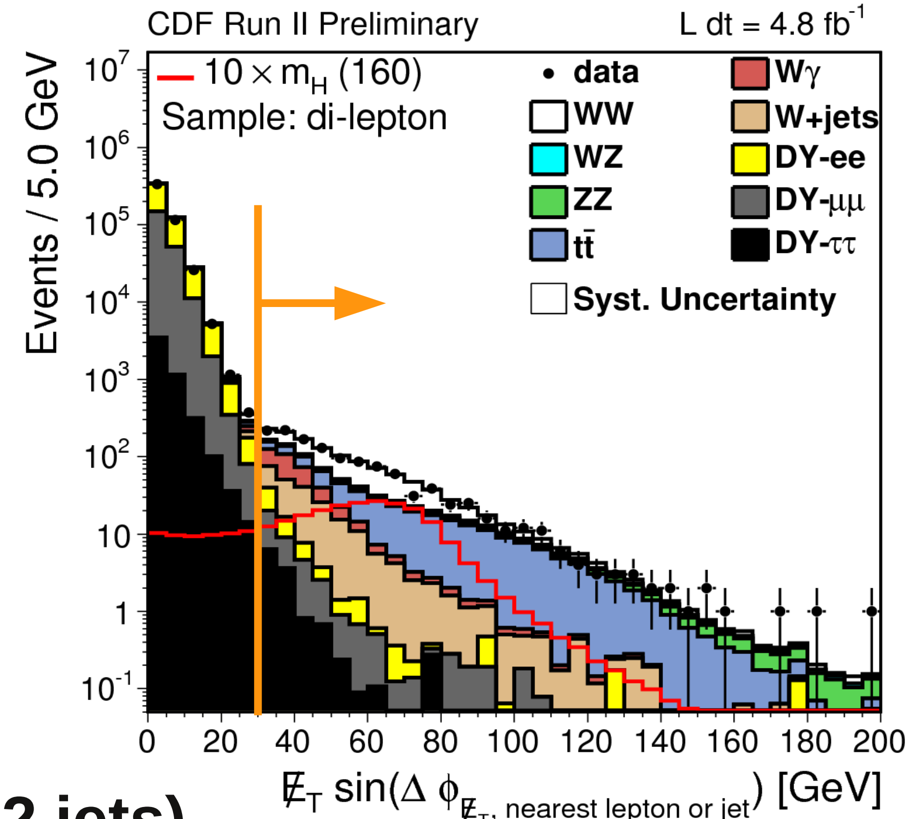
WW non resonant



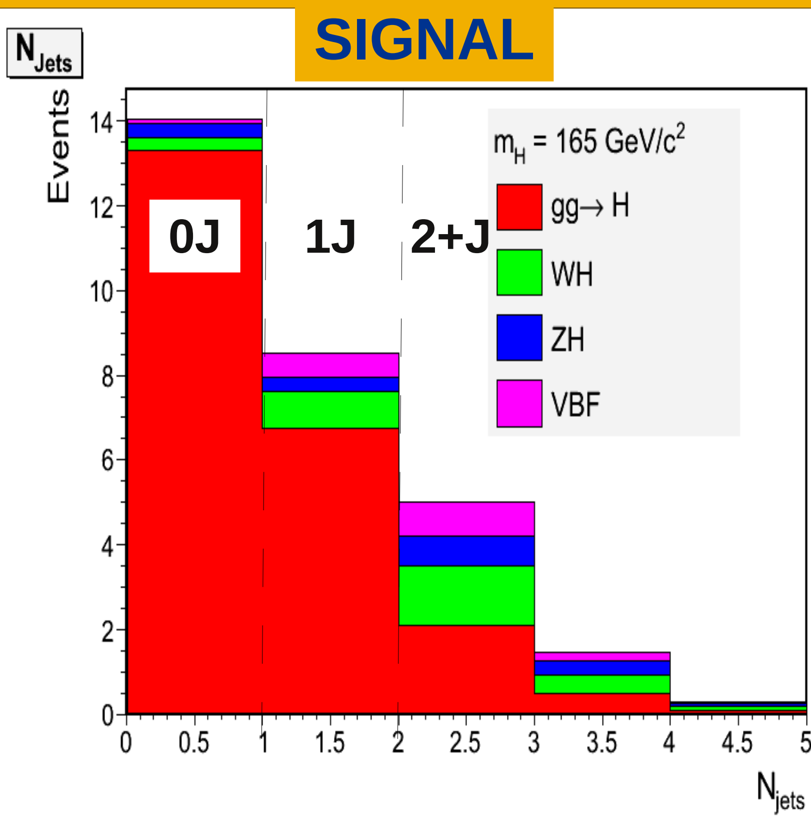
2 jets at LO: **tt,WZ,ZZ**
(tt mainly with b-jets)

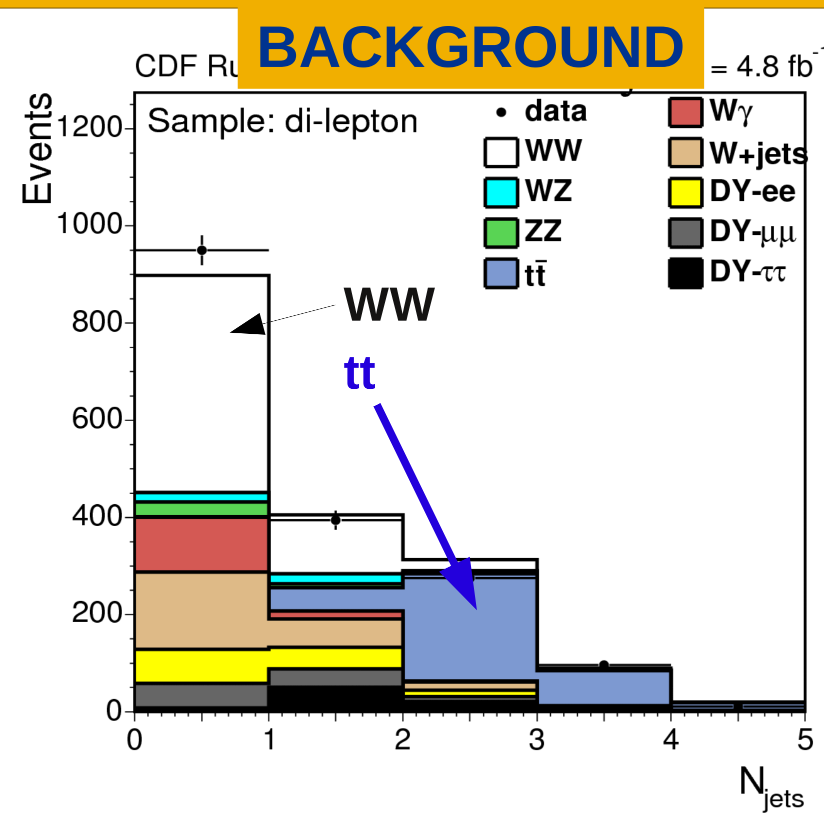
Event selection

- **Two opposite sign, isolated leptons: ee, μμ, eμ**
  - $p_T > 10$ (20) GeV (Trigger)
- **Significant Missing Transverse Energy ($\not{E}_T$)**
  - suppress Drell-Yan
- **m(ll) > 16 GeV**
  - reject heavy flavor decays
- **Veto identified b-jets (if >= 2 jets)**
  - Reduce Top contribution



Sample composition



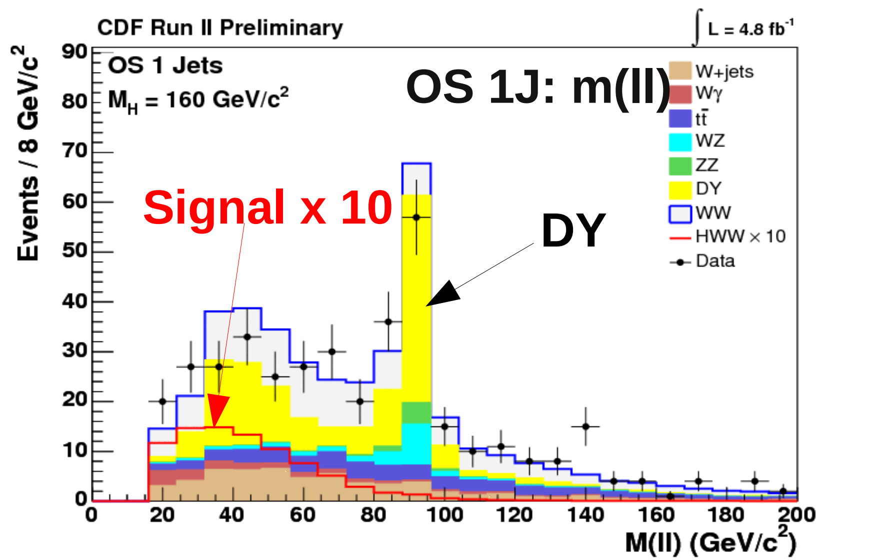


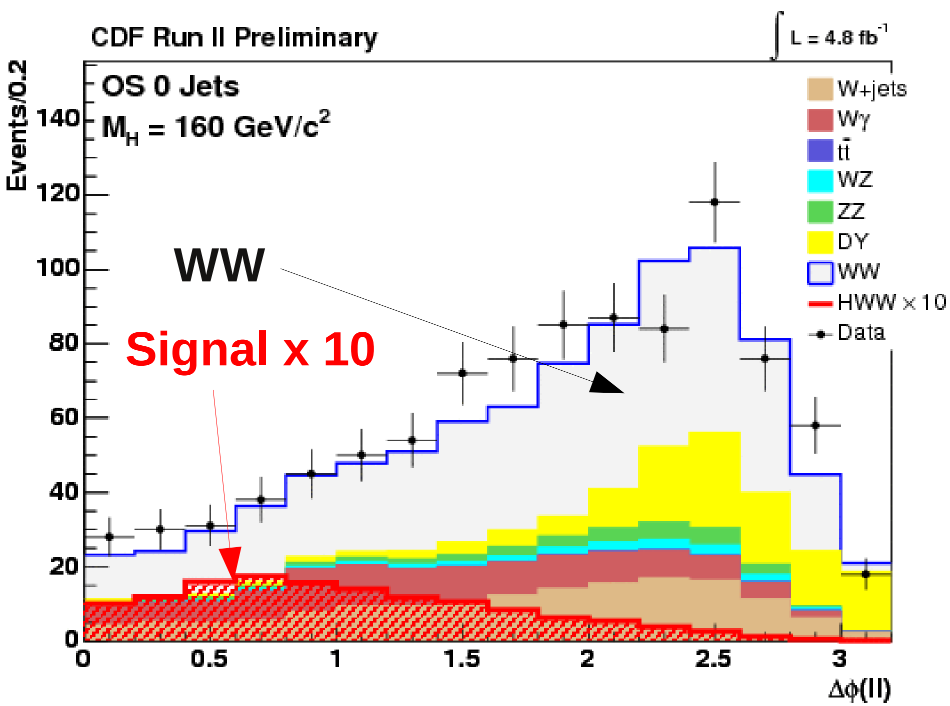
$M_H = 160$ GeV	Signal	Background	$S/\sqrt{B}$	Data
0 Jets	13.4 ± 1.8	893 ± 79	0.5	950
1 Jet	8.2 ± 1.8	406 ± 53	0.4	393
2+ Jets	6.4 ± 1.8	254 ± 33	0.4	224

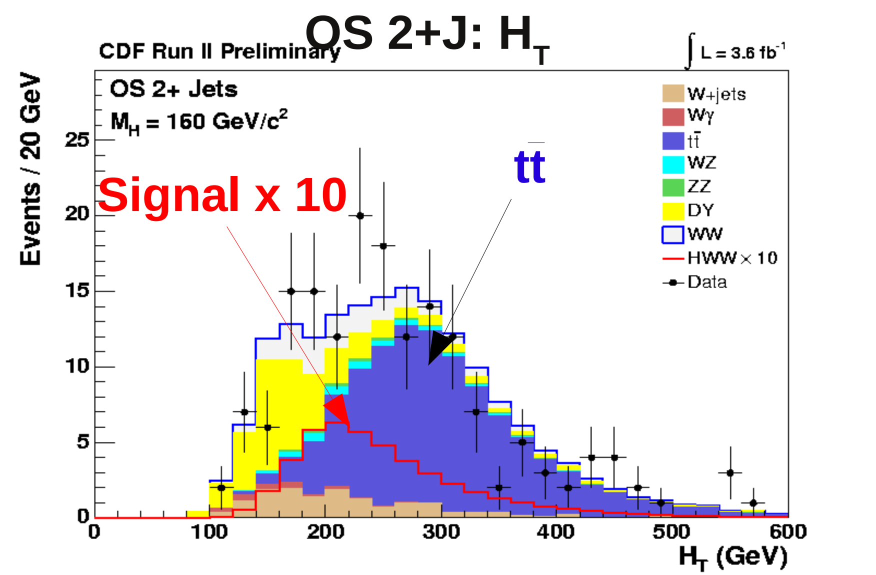
$\int \mathcal{L} = 4.8\ \text{fb}^{-1}$

Exploit Kinematic properties

- **Most effective depend on S,B**
  - Lepton-specific (p_T(l), …)
  - Angular ($\Delta\phi$(l,l), $\Delta\phi$(l,E_T), ...)
  - Kinematics (E_T, H_T, ...)

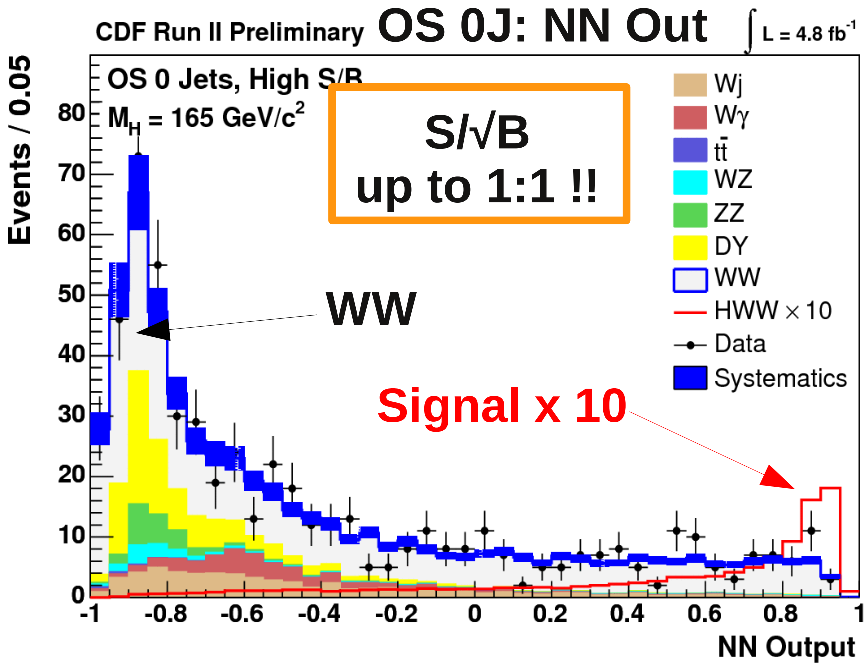


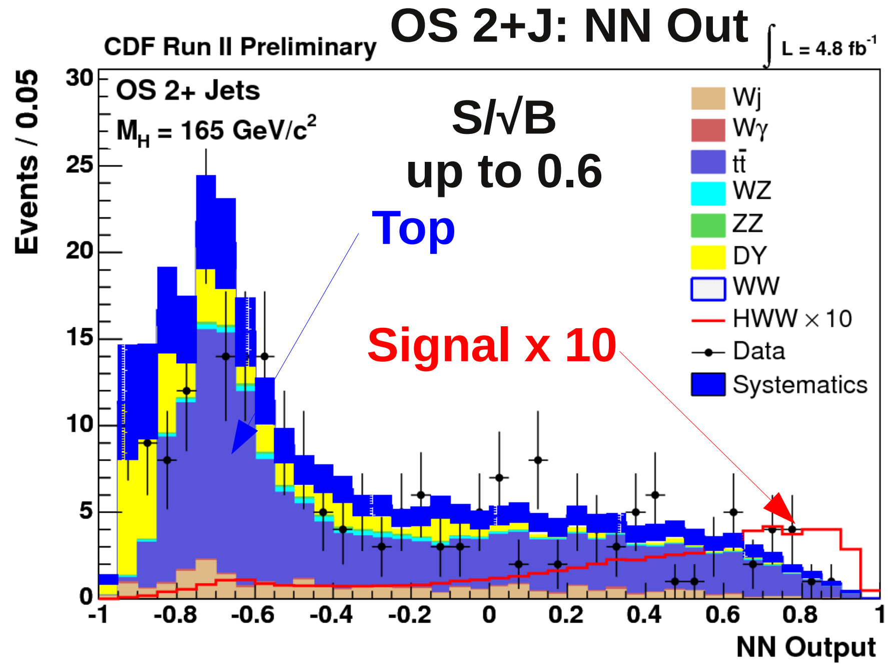




Improving S/B separation

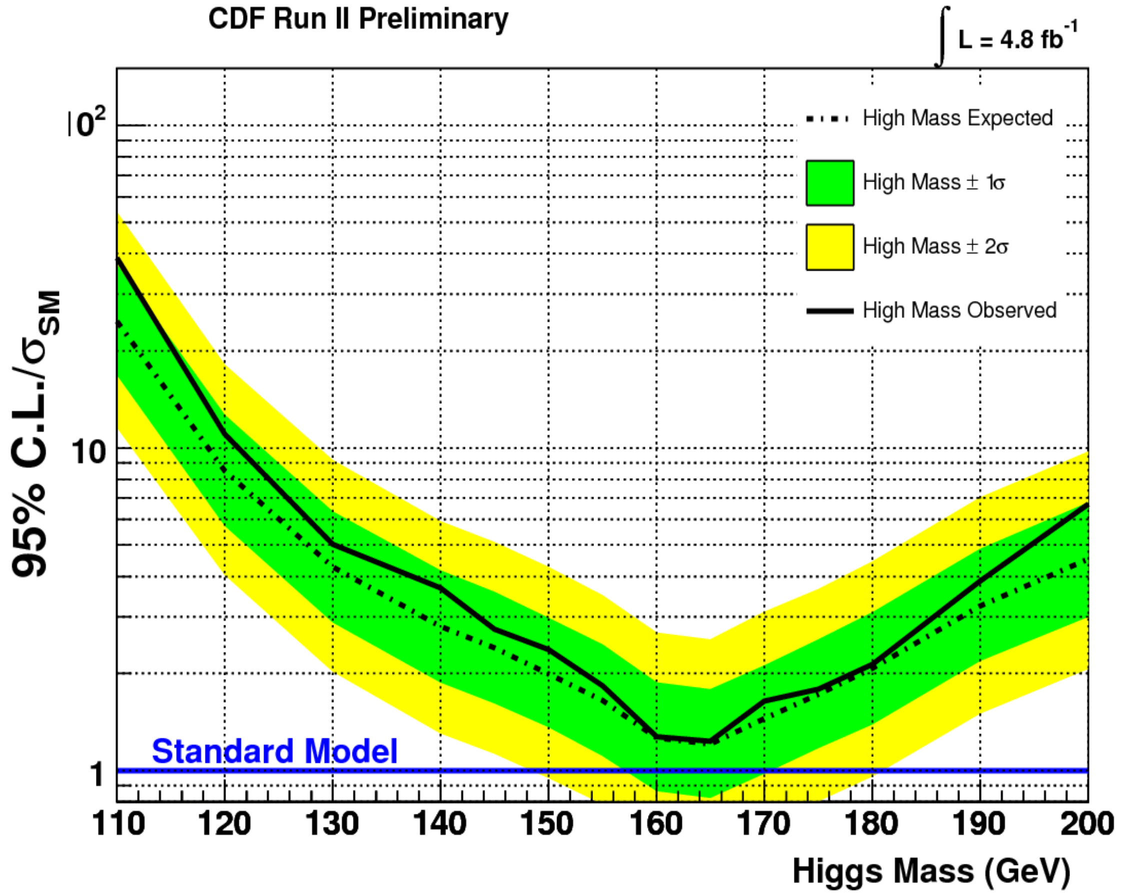
- **Use multivariate techniques to combine kinematic properties into a single discriminant**
- **Train one Neural Network for each jet multiplicity (0,1,2+) and Higgs mass hypothesis to probe**





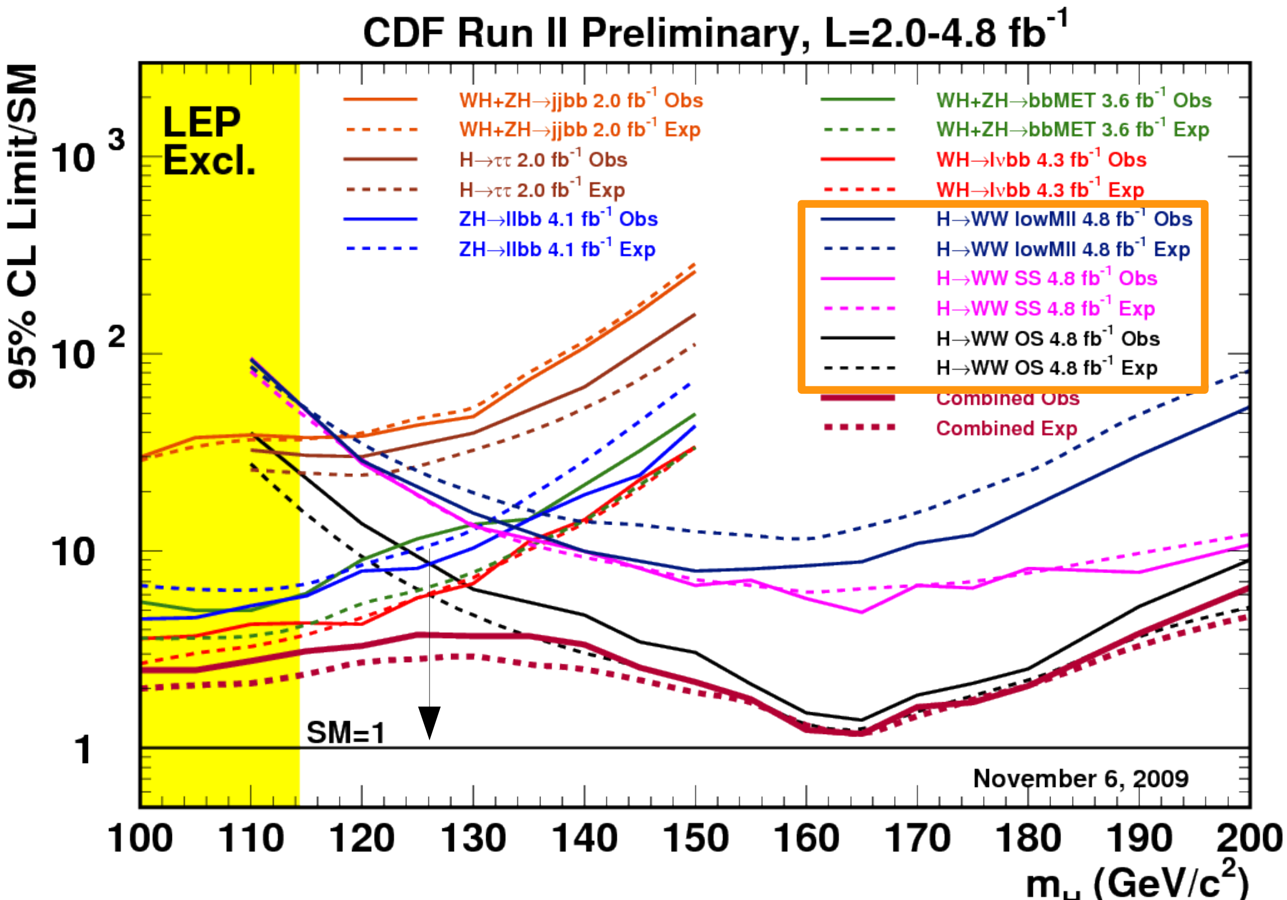
CDF H → WW results.. in 2009

- **No excess in data seen so far. We set 95% C.L. limits on Higgs production cross section (w.r.t. SM prediction)**



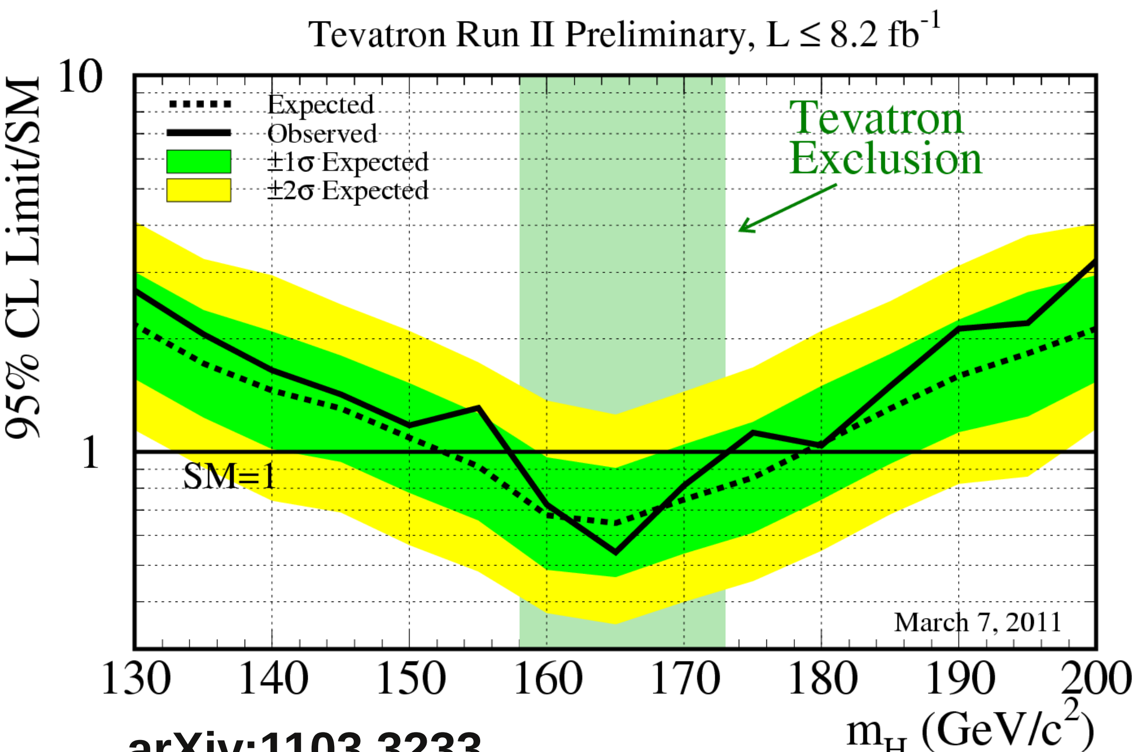
H → WW sensitivity

- No excess in data seen so far. We set 95% C.L. limits on Higgs production cross section (w.r.t. SM prediction)
- The most sensitive analysis for m_H >~ 125 GeV



This was summer 2009...

- **In 2009, using ~5fb-1 of data, CDF+D0 constrained the allowed Higgs boson mass beyond the LEP limits**
- **2011: exclusion 158 < m_H < 173 GeV**

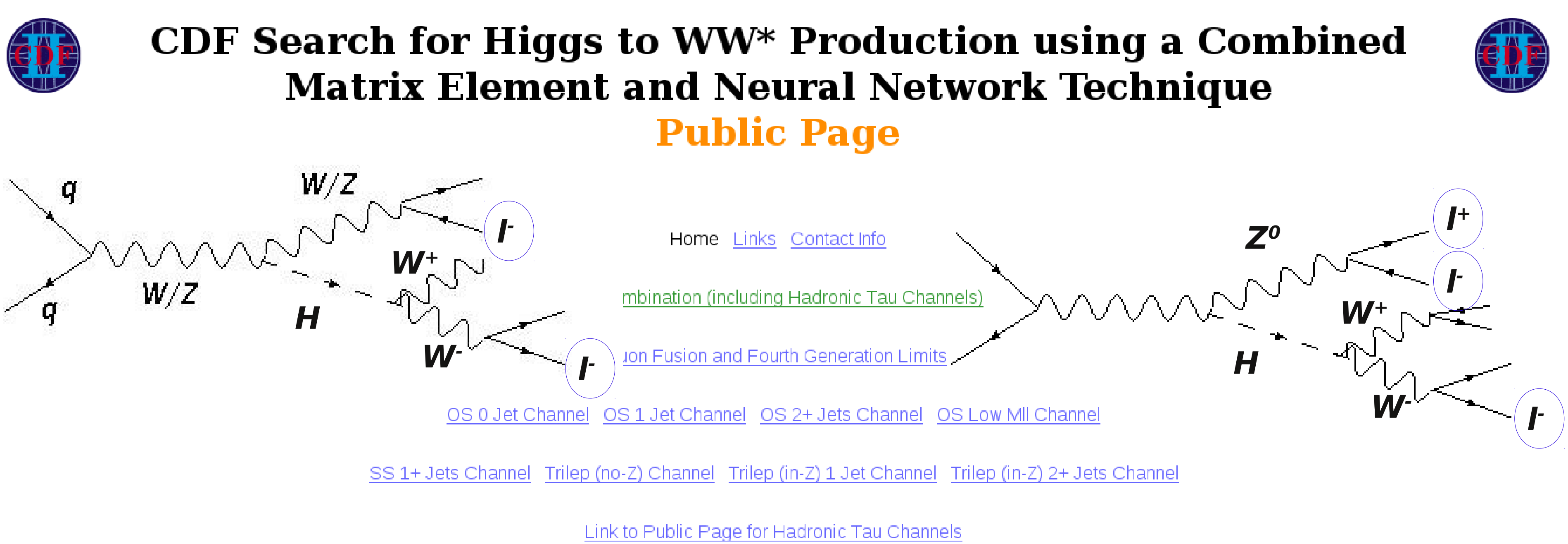


arXiv:1103.3233

Phys. Rev. Lett. **104**, 061802 (2010)

CDF Higgs sensitivity: today

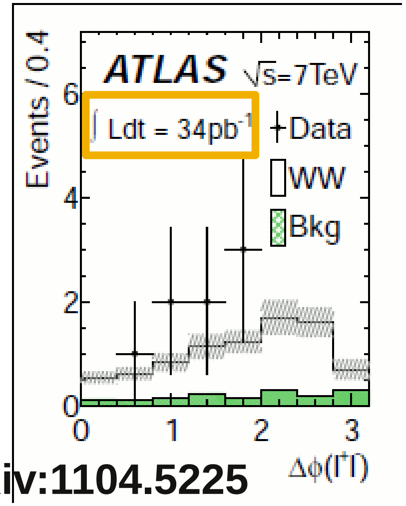
- **Nowadays almost doubled dataset: 7.1fb^{-1} analyzed**
  - **CDF Reached SM sensitivity! excludes 158 < m_H < 168 GeV!**
- **New final states explored and analysis improvements**



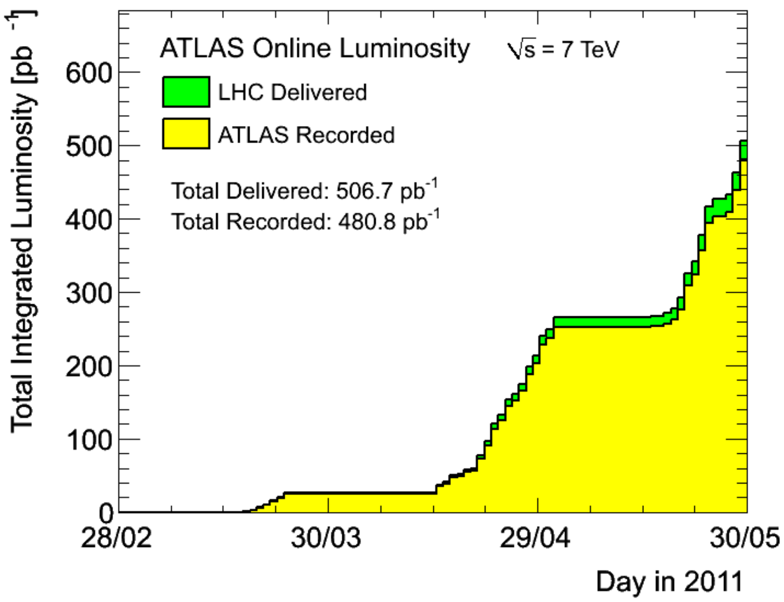
http://www-cdf.fnal.gov/physics/new/hdg/Results_files/results/hwwmenn_110304/

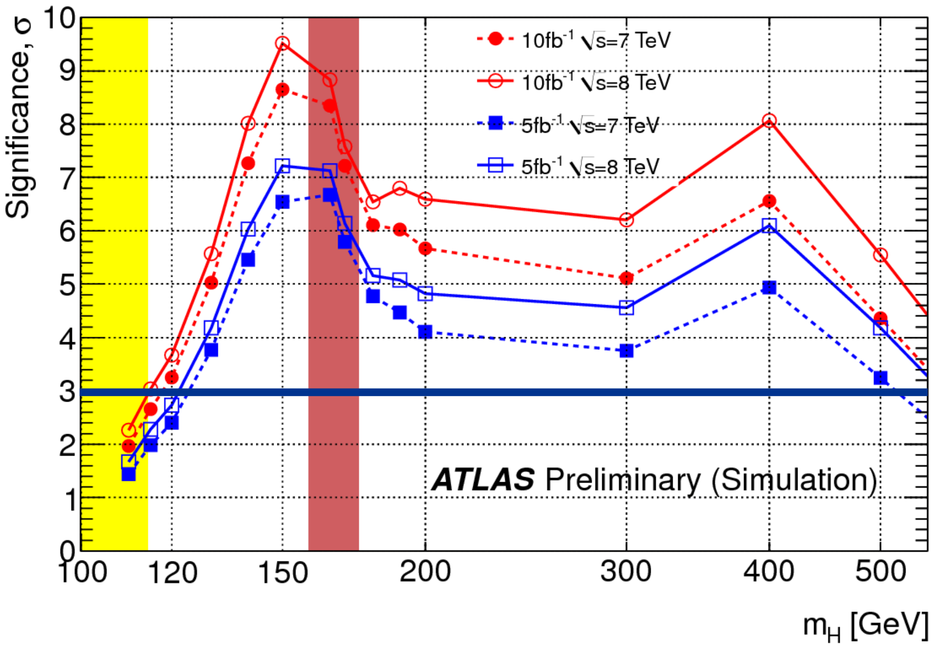
H → WW @ LHC in a nutshell

m_H=160 GeV	σ_H [pb] (inclusive)	$\frac{\sigma(H\to WW)}{\sigma(WW)}$
Tevatron (√s=1.96 TeV)	0.561	4 %
LHC (√s=7 TeV)	10.3	21 %



arXiv:1104.5225



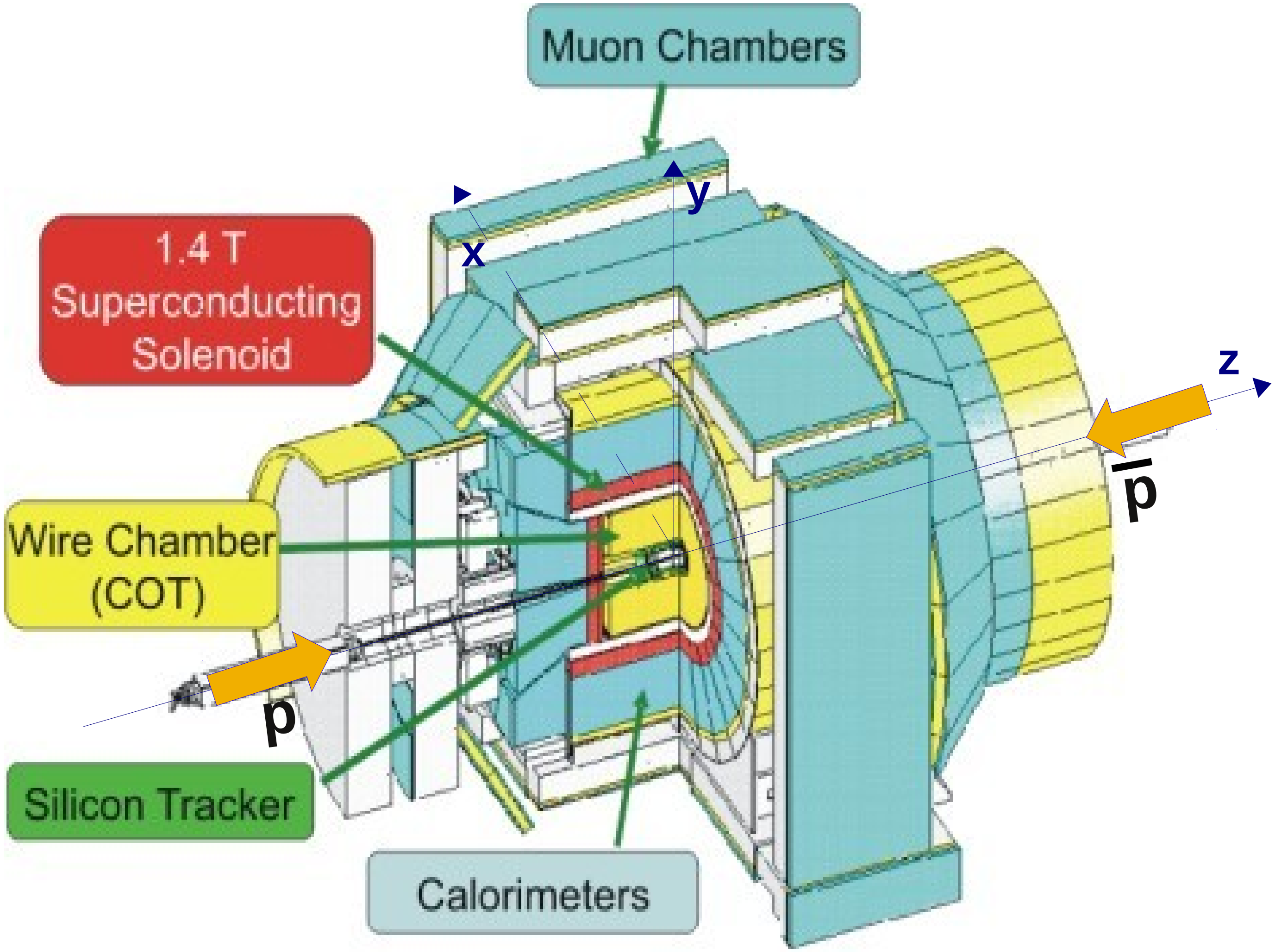


Conclusions & Acknowledgments

- **Direct search of H $\rightarrow$ WW gives the best sensitivity for most of the allowed SM Higgs boson mass range**
  - No evidence yet: Tevatron limits exclude $158 < m_H < 173$ GeV
- **Tevatron and LHC will probe the SM Higgs soon**
  - It's a very exciting time to be Higgs hunters!
- **A special thanks to Donatella Lucchesi, Eric James, and all the CDF HWW group**

BACKUP

CDF detector

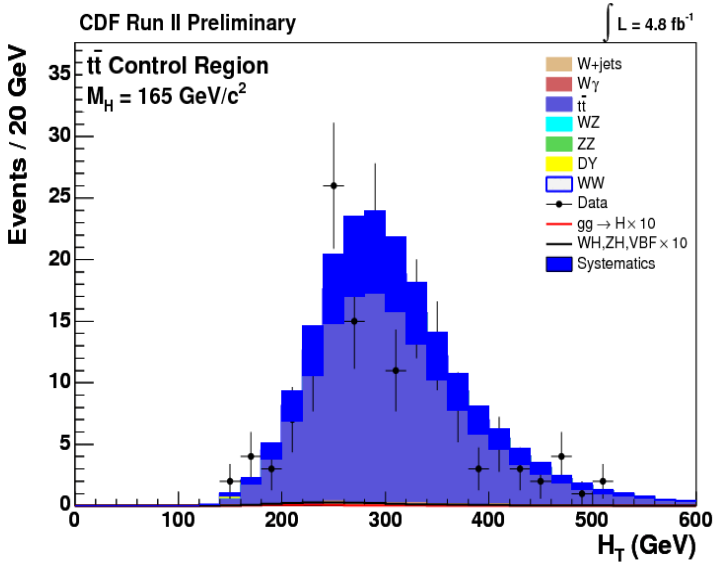


Background modeling

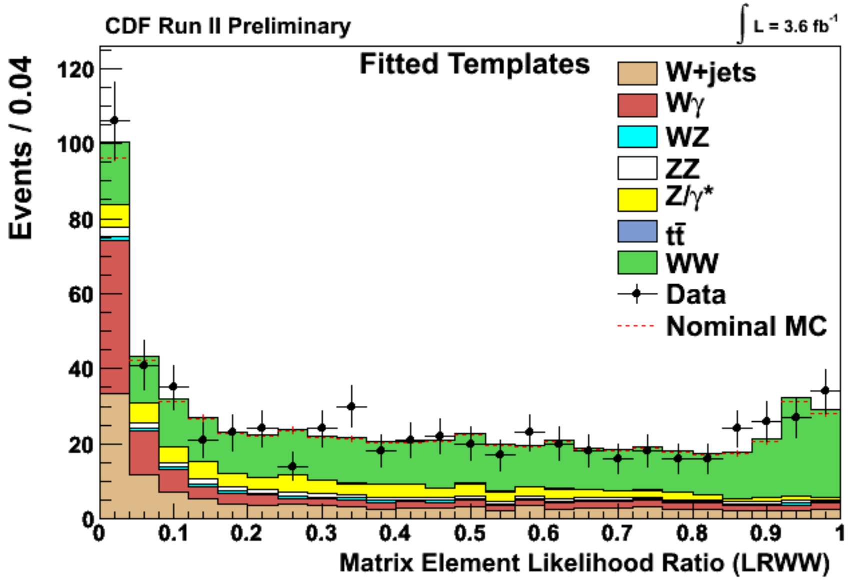
Background from simulation and data-driven techniques

(1) Orthogonal kinematic region

(2) Measurements of specific process cross sections using the same analysis techniques (and software)



1. >= 2 jets with identified b-jet



2. $\sigma(WW) = 12.1^{+1.8}_{-1.7}\ pb$

Theory: σ = 12.4 pb

(PRL 104.201801, 2009)