Exotic Higgs Searches at the Tevatron

Michael Mulhearn

Columbia University

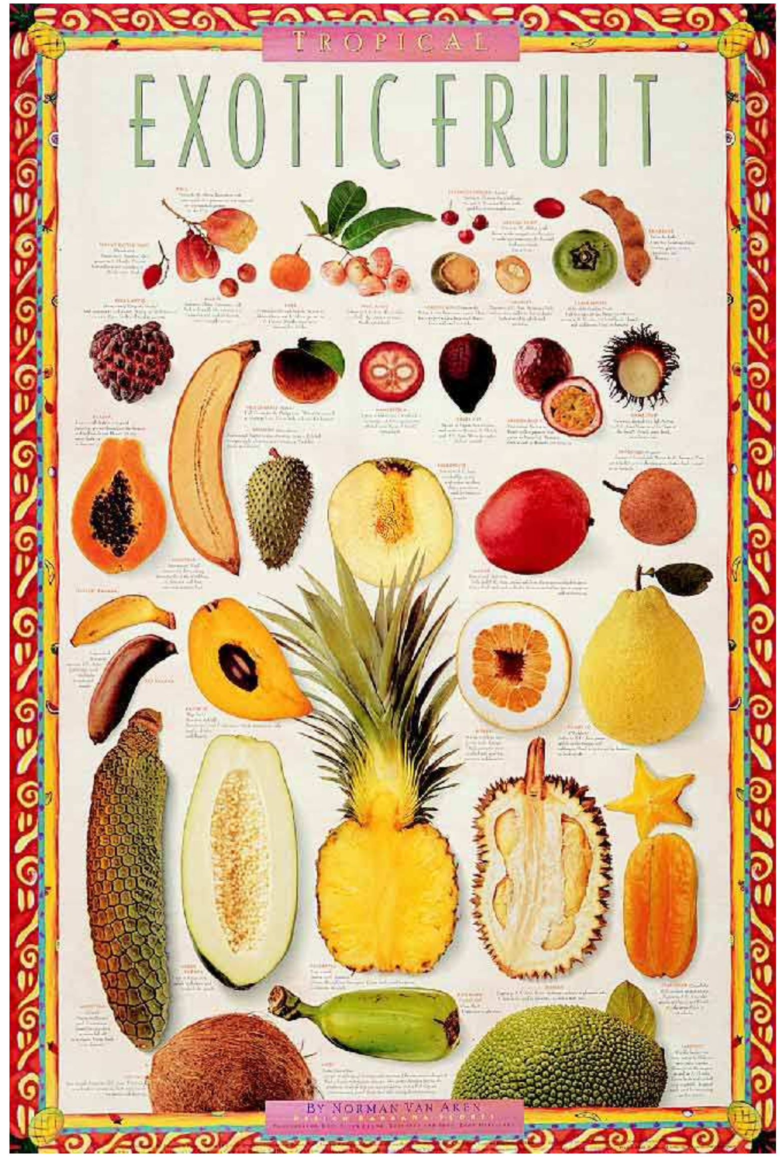
On Behalf of the CDF and DØ Collaborations

Moriond QCD 2008

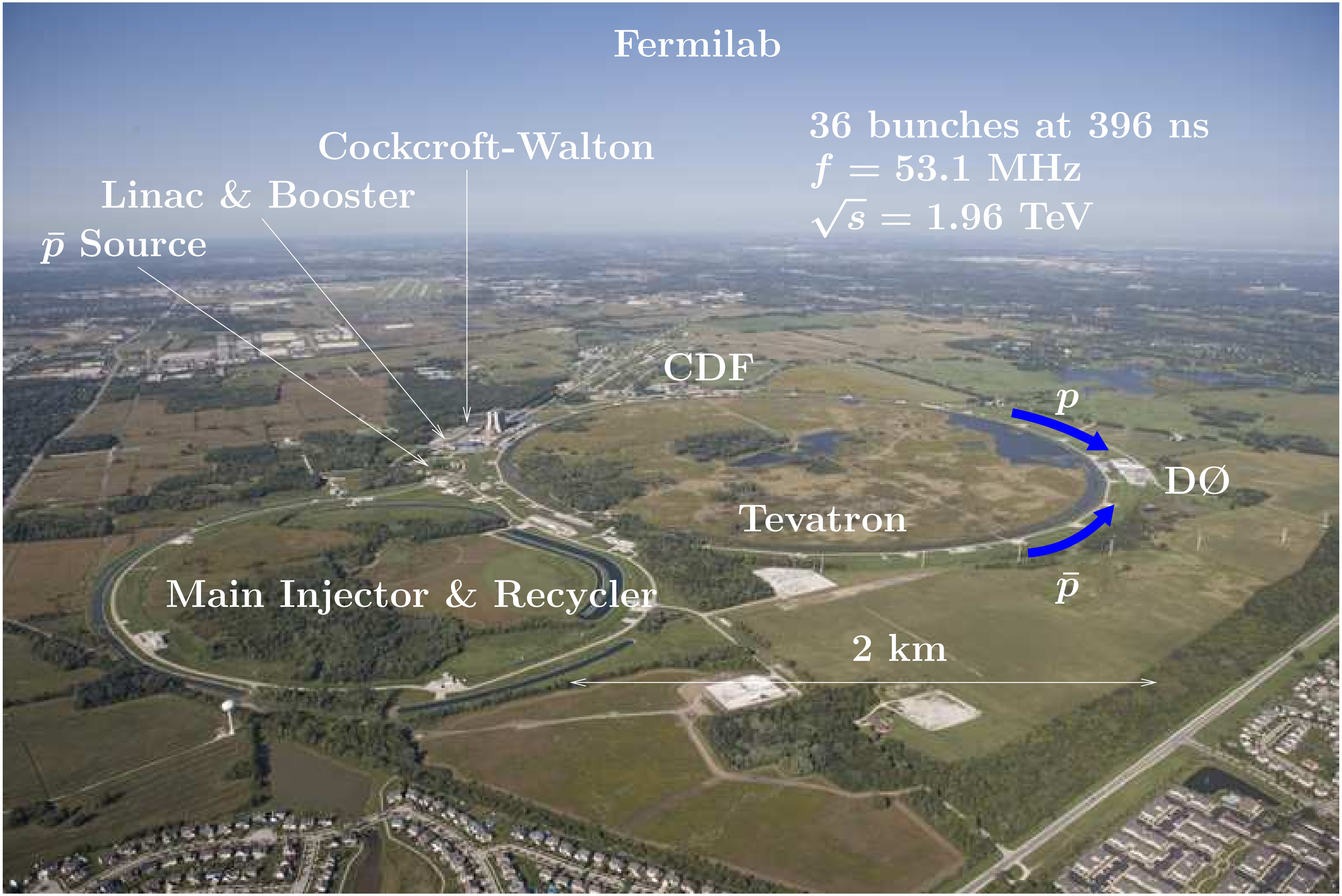
March 11, 2008

The *Exotic* Higgs Boson

- What do we mean by *exotic* Higgs?
- Total Higgs discoveries to date: 0
- There is no *experimental preference* for a Standard Model (SM) Higgs boson.
- *Any Higgs boson is exotic!*
- Tevatron Higgs searches covered in this talk:
  - ▷ $H \to \gamma\gamma$:
    - Gluon-gluon fusion
    - Vector-boson fusion
    - Associated production
  - ▷ Limits on a fourth generation and Higgs.
  - ▷ Doubly-charged Higgs: $H^{\pm\pm}$

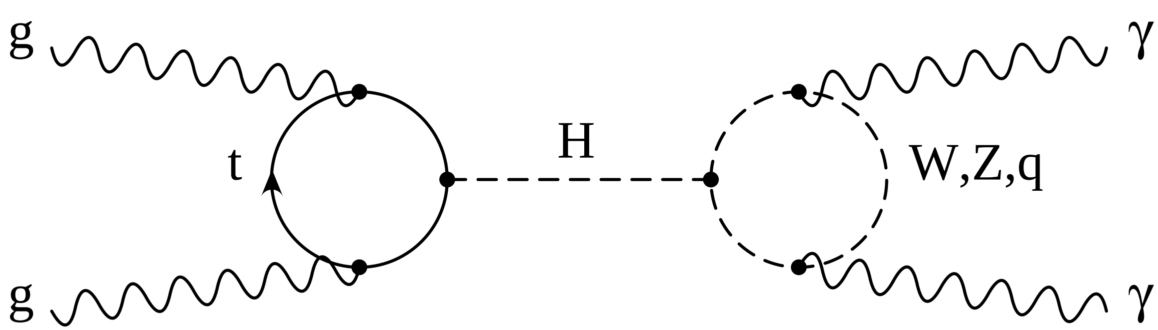


The Tevatron



$H \to \gamma\gamma$

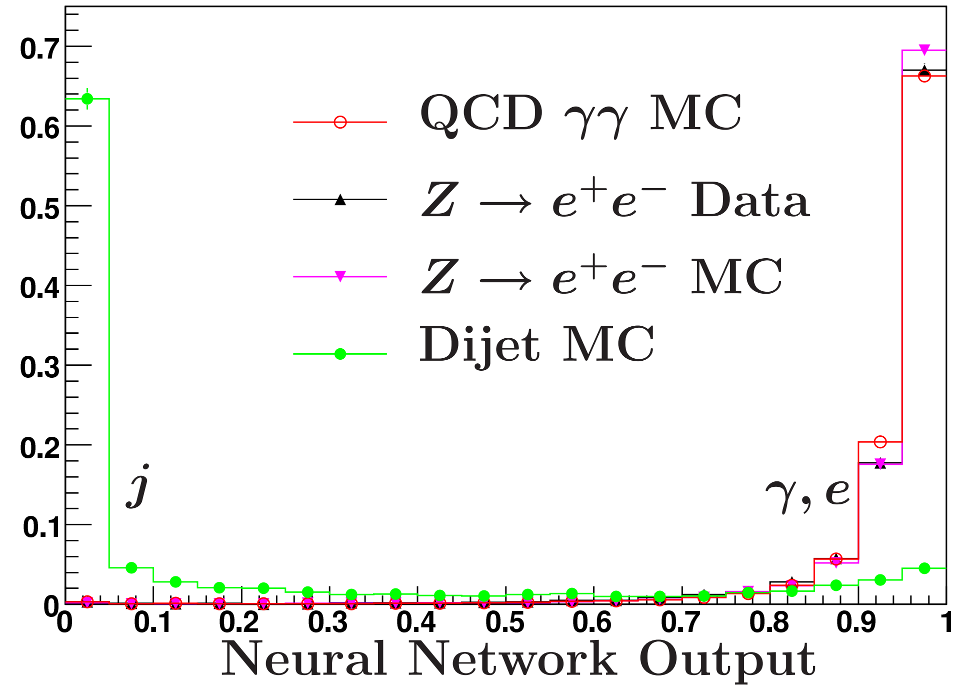
- $H \to \gamma\gamma$ is a rare SM decay, but is enhanced in fermiophobic models.
  - ▷ top-color, large extra dimensions, MSSM loop corrections.
- New DØ Search optimized for SM gluon-gluon fusion:



- Select events with two photons:
  - ▷ Reconstruct cluster in EM calorimeter: $p_T > 25$ GeV.
  - ▷ Veto on nearby track to distinguish γ from e.
  - ▷ Require calorimeter isolation to distinguish γ from jet (j):
    - Cuts based on EM energy surrounding cluster, and nearby hadronic energy.
    - Neural Network (NN) which combines three EM shower shape variables.

$H \to \gamma\gamma$ Background Determination

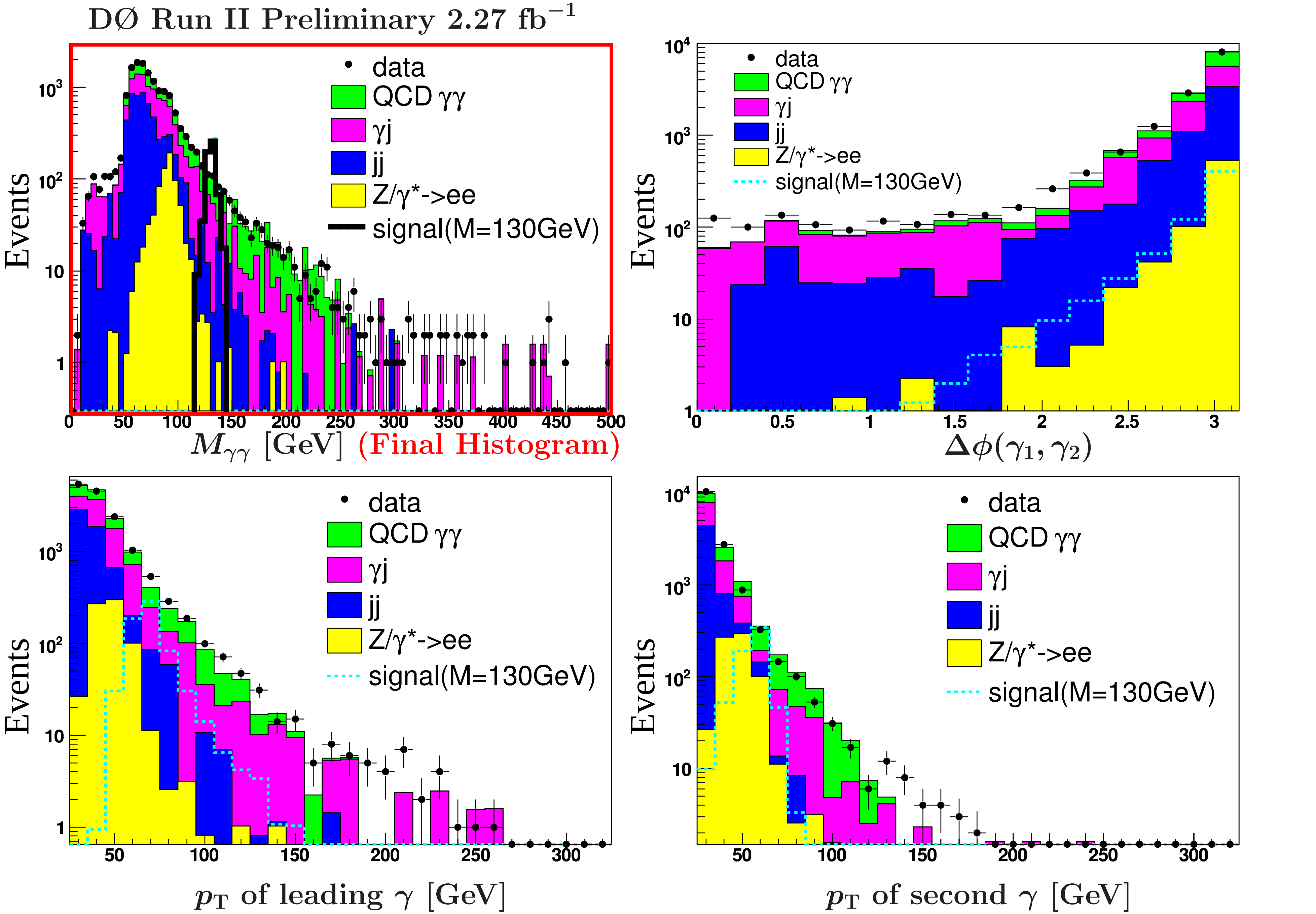
- Primary backgrounds:
  - ▷ $Z/\gamma^* \to e^+e^-$ with misidentified e.
  - ▷ Direct QCD diphoton production.
  - ▷ QCD jets faking photons:
    - $\gamma + j$ and $j + j$.
    - Neural Network provides excellent $j \to \gamma$ discrimination.



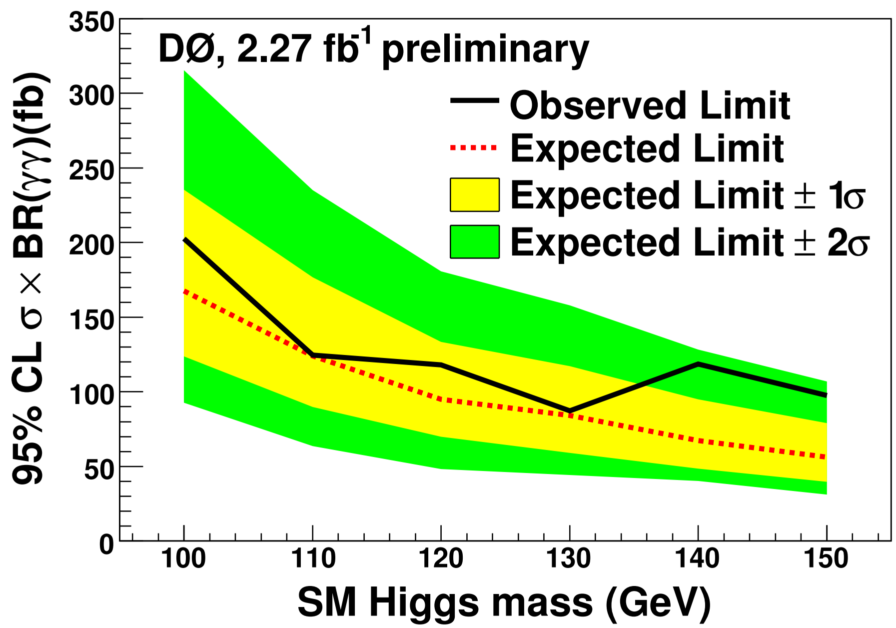
- Determine efficiencies from control samples:
  - ▷ $\gamma \to \gamma$, $e \to \gamma$, and $j \to \gamma$.
- Monte Carlo estimation of $Z \to e^+e^-$ and direct QCD diphotons.
- QCD jets faking photons: $\gamma + j$ and $j + j$.
  - ▷ Solve linear equation for true populations from tagged populations.

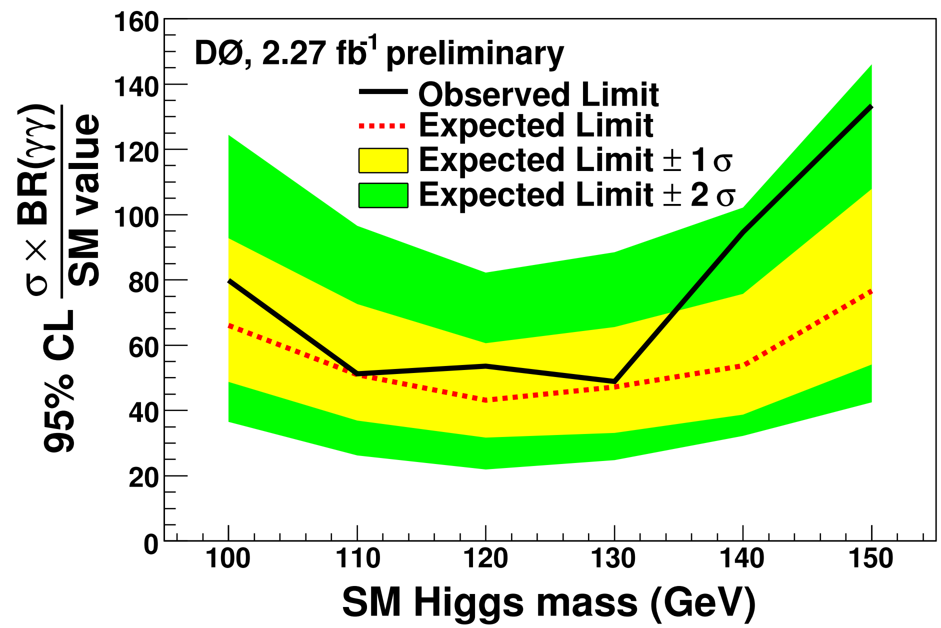
$$(N_{\mathrm{ff}}, N_{\mathrm{fp}}, N_{\mathrm{pf}}, N_{\mathrm{pp}}) = E \times (N_{jj}, N_{j\gamma}, N_{\gamma j}, N_{\gamma\gamma})$$

Data / Monte Carlo Comparisons in $H \to \gamma\gamma$



New DØ Results from $H \to \gamma\gamma$

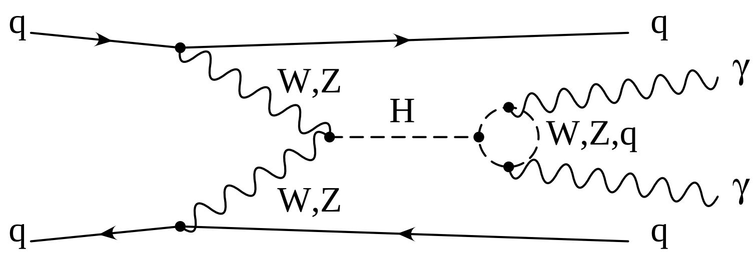


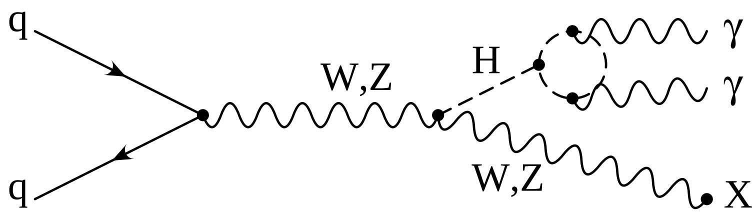


- No excess over background observed, set a cross-section limit.
- Compare to Standard Model, can superimpose other theory curves.
- Use CL_s limit setting procedure, a modified frequentist approach.
  - ▷ Treat each bin in each measurement as separate counting experiment.
  - ▷ Avoids unwarranted exclusion from background fluctuation: $CL_s = CL_{s+b}/CL_b$.
  - ▷ Systematics included as correlated fluctuations in expected signal and background.

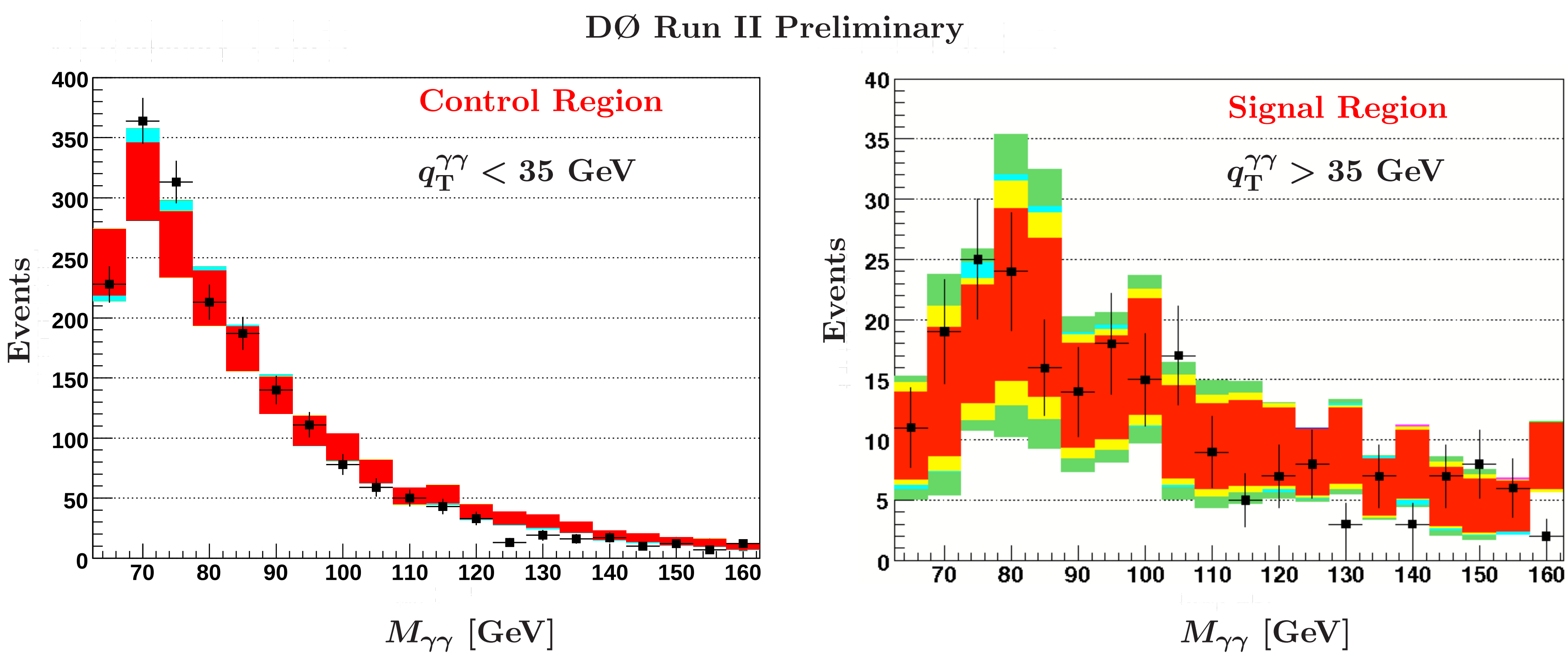
DØ $H \to \gamma\gamma + X$

- Fermiophobic Higgs by vector-boson fusion or associated production:

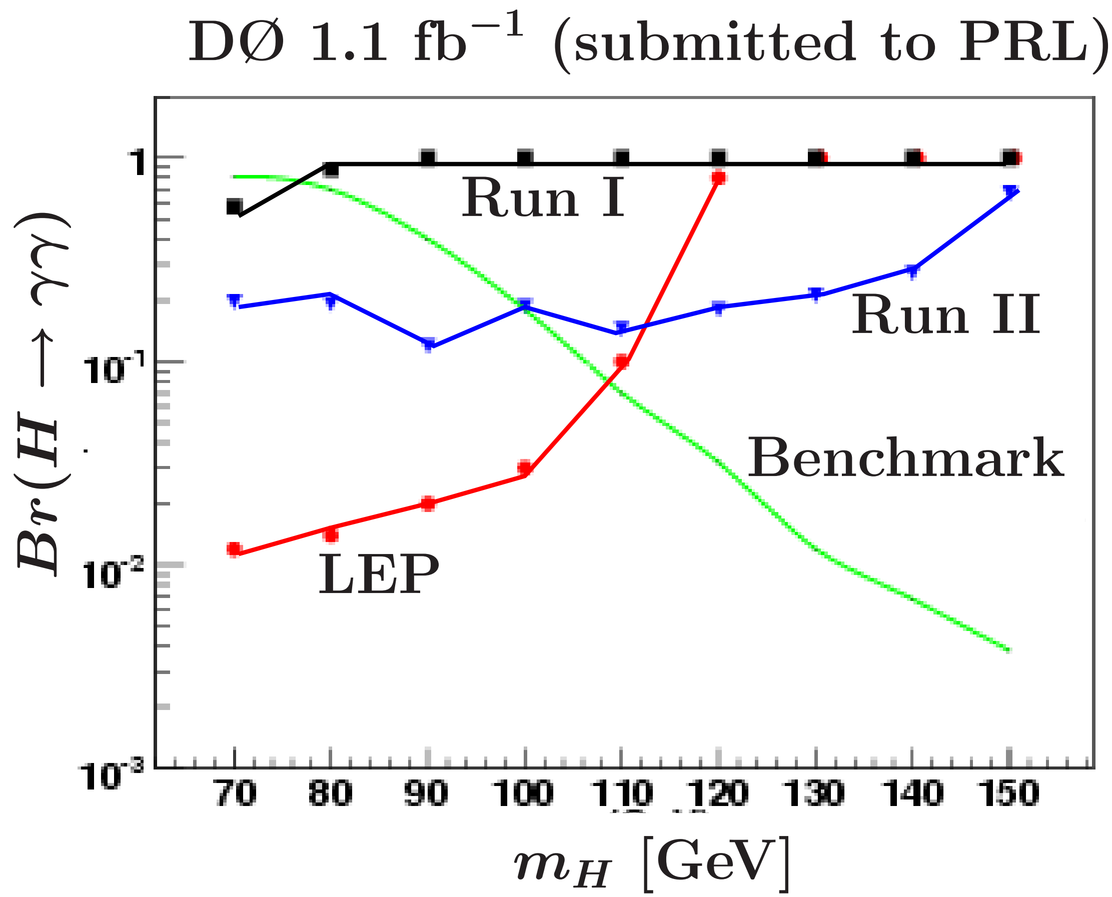




- Two isolated photons with $p_T > 25$ GeV, backgrounds from templated fits.

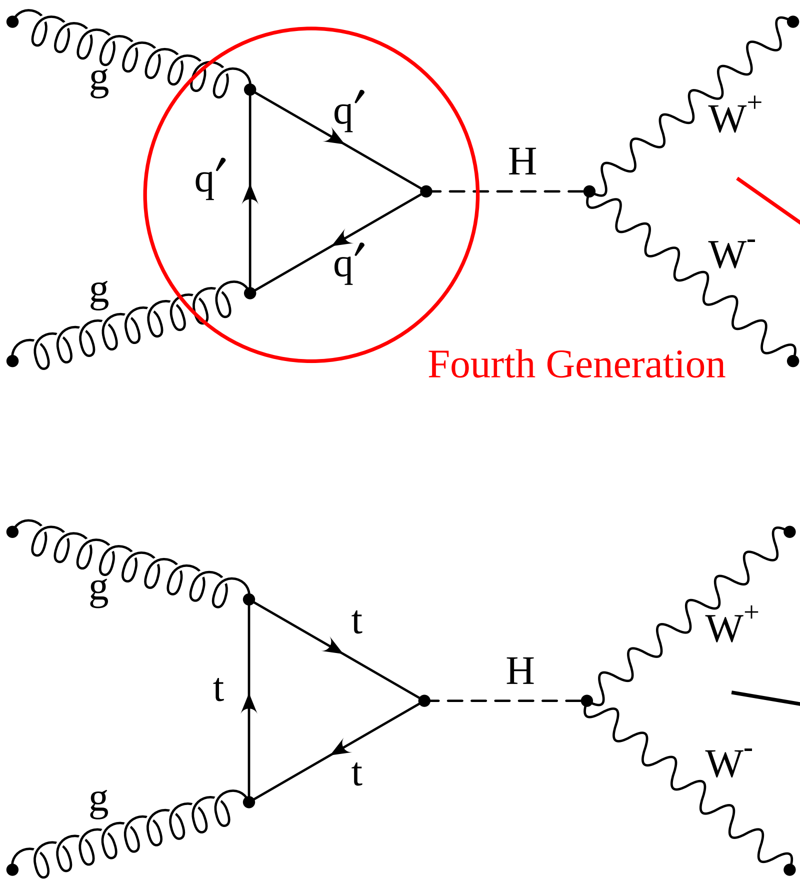


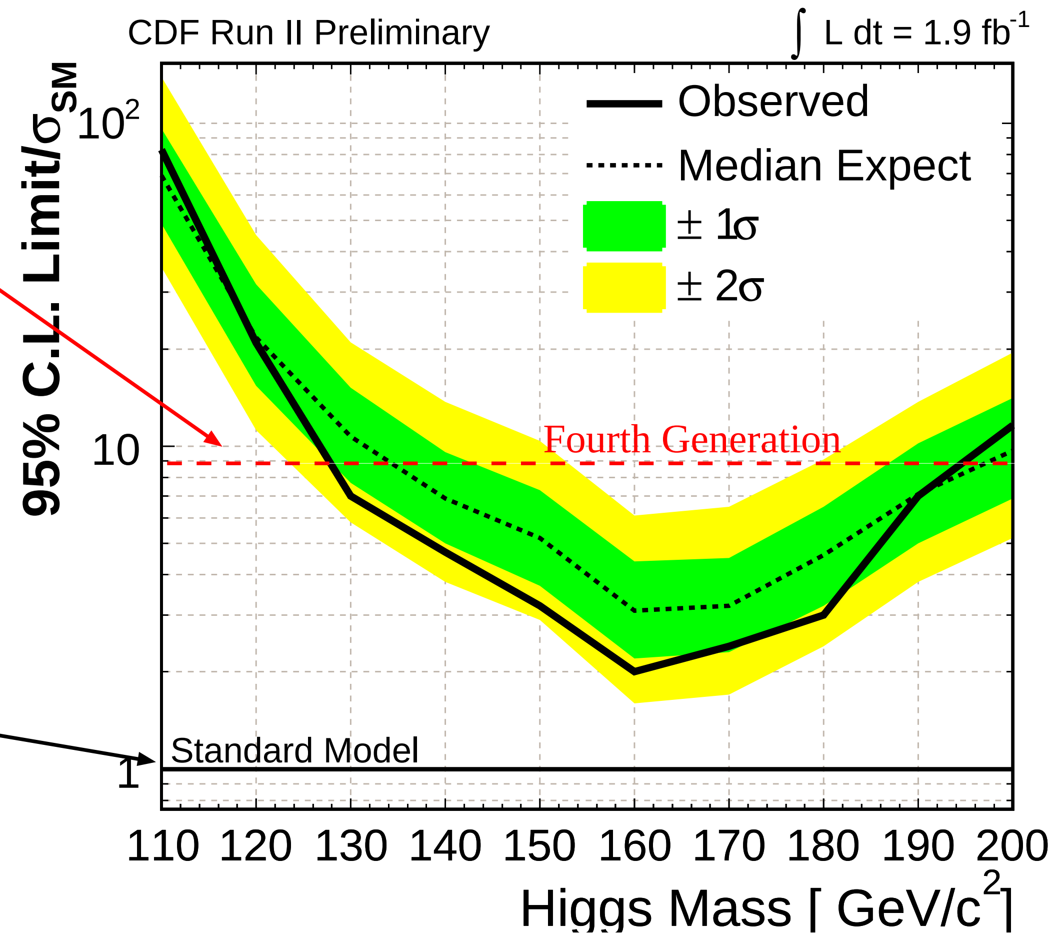
New Results from DØ $H \to \gamma\gamma + X$



- Benchmark couplings: Gauge Bosons same as SM, zero for fermions.
- No excess over background observed, set limit with CL_s method.
- This result: $m_H > 100$ GeV at 95% CL. (LEP $m_H > 109.7$ GeV.)
- But, improves limits on Br above $m_H > 120$ GeV.

CDF Fourth Generation and Higgs

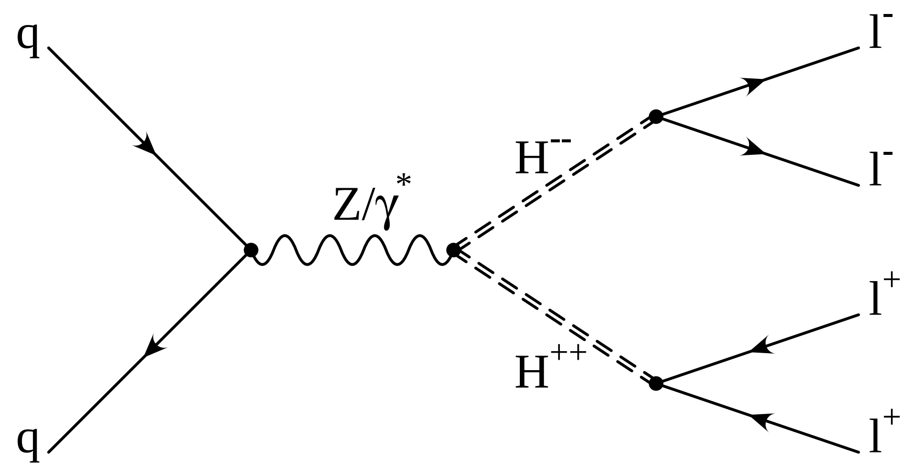




- Interpret SM $H \to WW$ Higgs limit in context of a fourth generation.
- Production cross-section larger due to additional quarks with large mass.
- Result: 130 GeV $< m_H <$ 195 GeV excluded at 95% CL.

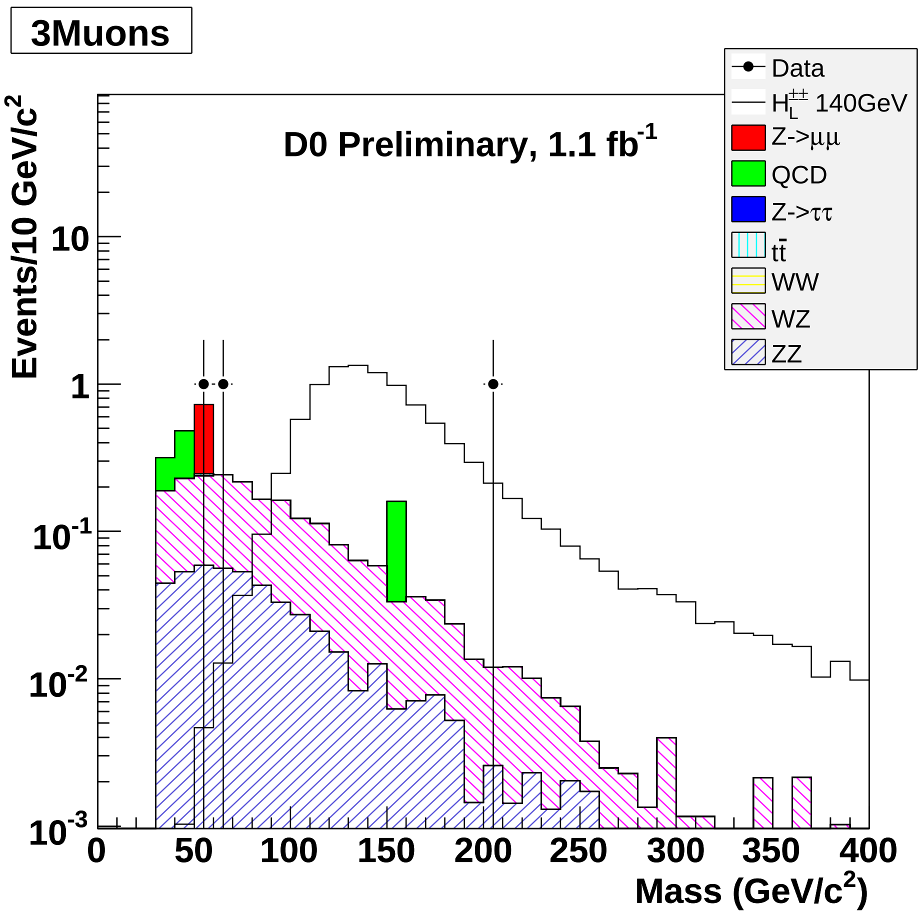
Doubly-charged Higgs $H^{\pm\pm}$

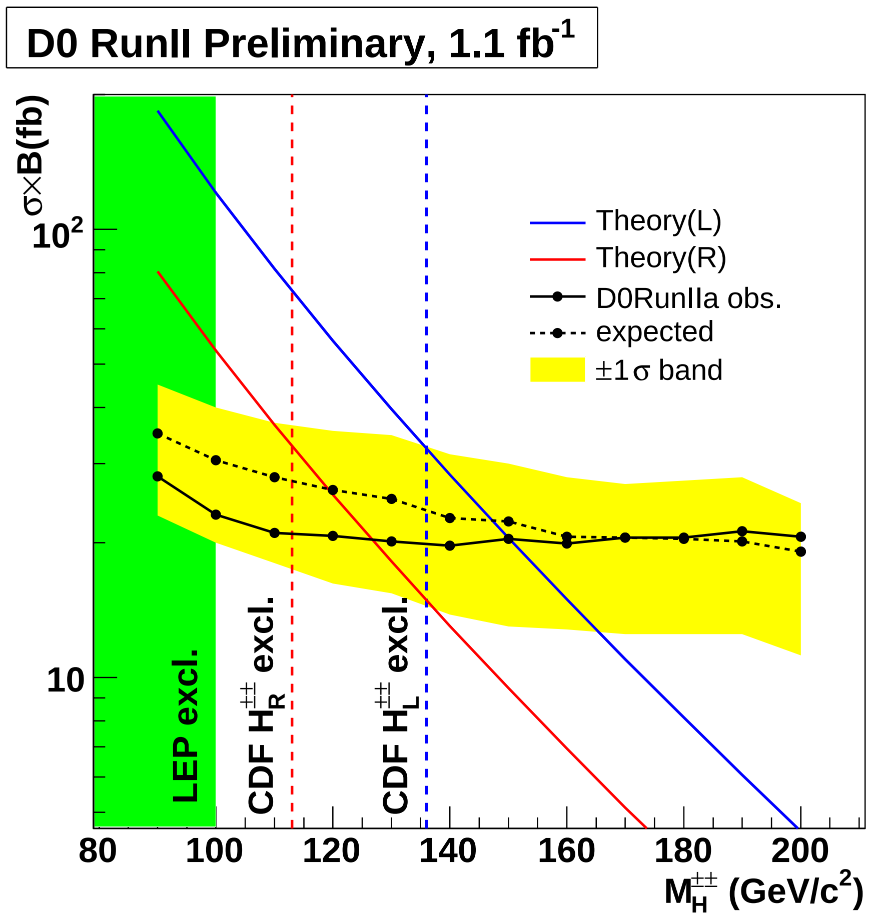
- Doubly charged Higgs: left-right symmetric, Higgs triplet, little Higgs models.
- CDF results:
  - ▷ $H^{++}H^{--} \to l^+l^+l^-l^-$
  - ▷ $H^{++}H^{--} \to \mu^\pm\mu^\pm e^\mp e^\mp$
  - ▷ $H^{++}H^{--} \to l^+\tau^+l^-\tau^-$
- New DØ result:
  - ▷ $H^{++}H^{--} \to \mu^+\mu^+\mu^-\mu^-$.



- Select two muons with $p_T > 15$ GeV.
  - ▷ Charge well determined, require minimum number of hits in tracker.
  - ▷ Muon isolation: sum of nearby energy and tracks.
  - ▷ $\Delta\phi(\mu_1, \mu_2) < 2.5$
  - ▷ Two muons have same sign.
  - ▷ One more muon passes above (except minimum hits.)
- From MC: WZ, ZZ, WW, $Z \to \mu^+\mu^-$, $t\bar{t}$, $Z \to \tau^+\tau^-$
- QCD background determined from data.

DØ Results from $H^{++}H^{--} \rightarrow \mu^+\mu^+\mu^-\mu^-$





- No excess observed, set cross-section limit with CL_s method.
- Mass limit: $m_{HR} > 127$ GeV and $m_{HL} > 150$ GeV.

Conclusion

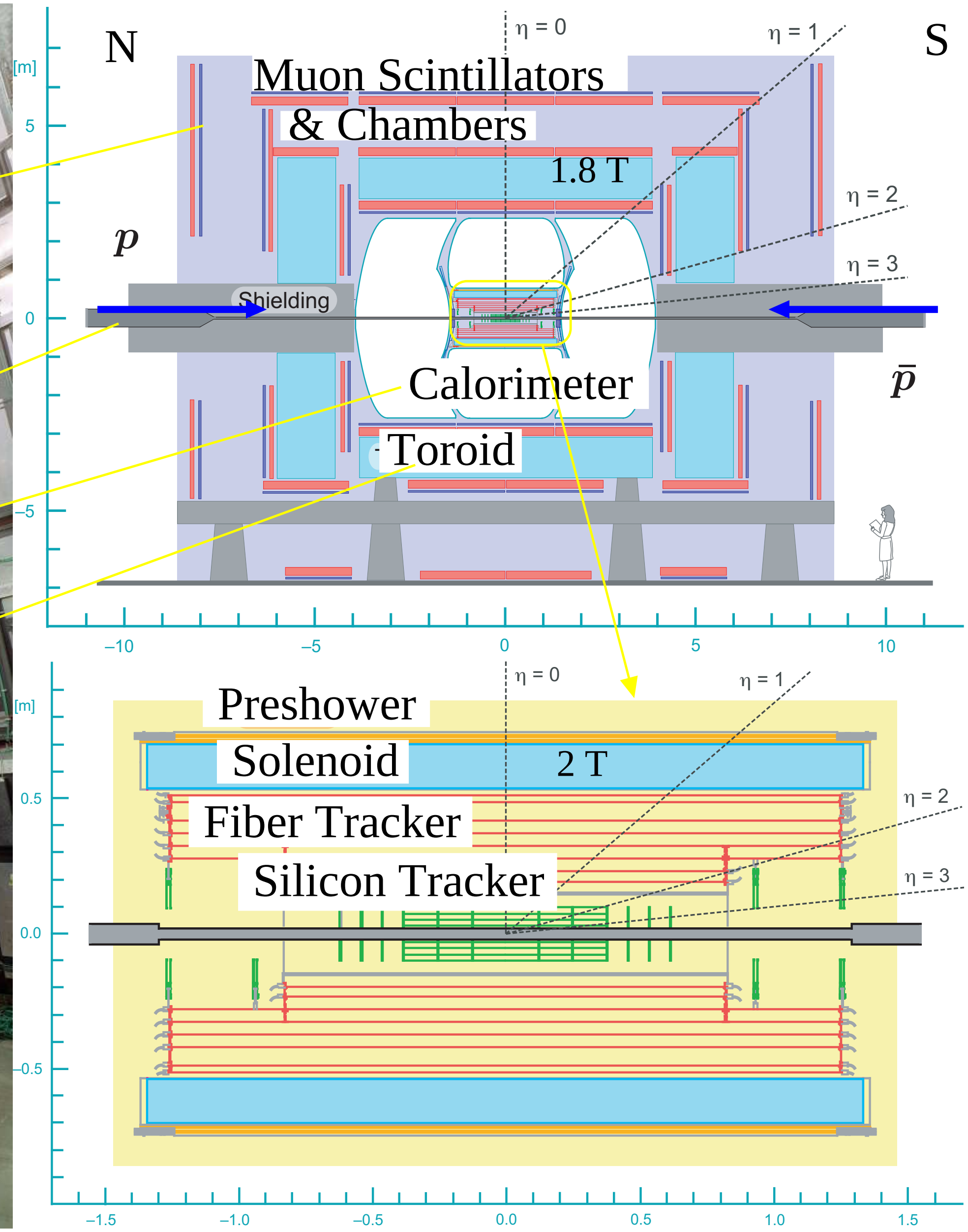
- Number of discovered Higgs (Exotic or Otherwise): 0
- Most analyses shown use first $1 - 2\ \mathrm{fb}^{-1}$ of data.
- Expect up to $6\ \mathrm{fb}^{-1}$ of data by 2009.
- Mature well-understood experiments with data pouring in!
- Renewed interest and much work improving Higgs sensitivity.
- No need to wait for a factor of two: *Exotic* Higgs sensitivity is growing!

&

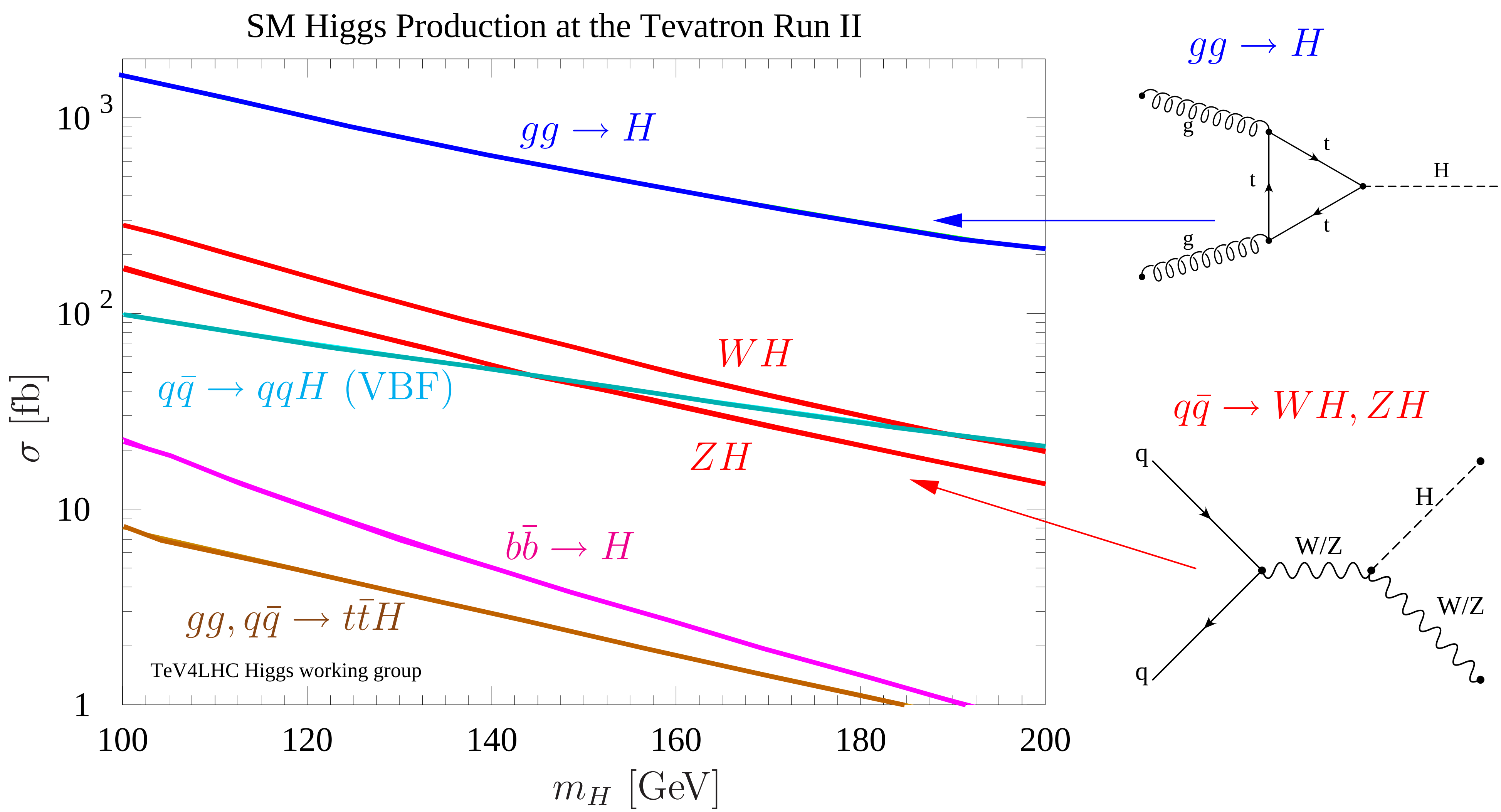
The End

Backup Slides Follow

The DØ Detector for Run II



Higgs Boson Production



- Vector-boson-fusion also being considered, enhanced cross-section at LHC.

Decays of the Higgs Boson

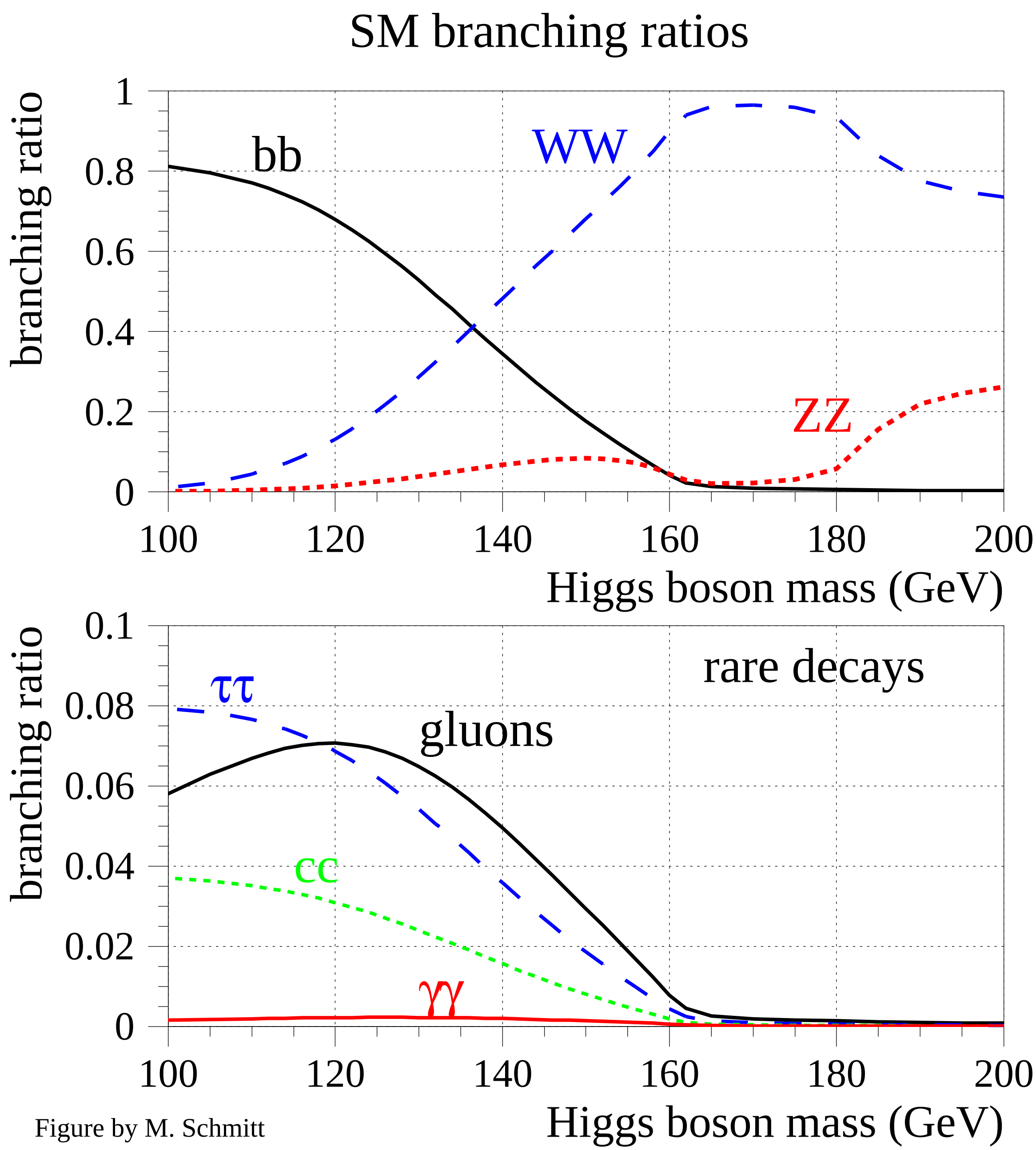


Figure by M. Schmitt

- Primary Decays:
  - ▷ $m_H < 135$ GeV: $H \to b\bar{b}$
  - ▷ $m_H > 135$ GeV: $H \to WW$
- $H \to b\bar{b}$ is difficult at a hadron collider:
  - ▷ $\sigma(gg \to H) \sim 1$ pb
  - ▷ $\sigma(q\bar{q} \to b\bar{b}) \sim 10^6$ pb