5. Higgs Boson Search

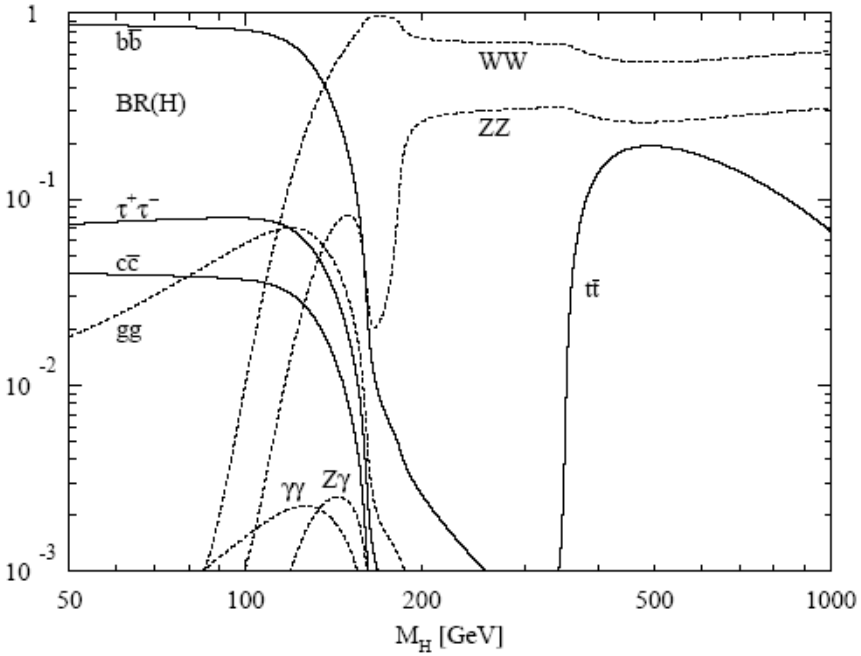
Higgs decay widths / branching ratios:

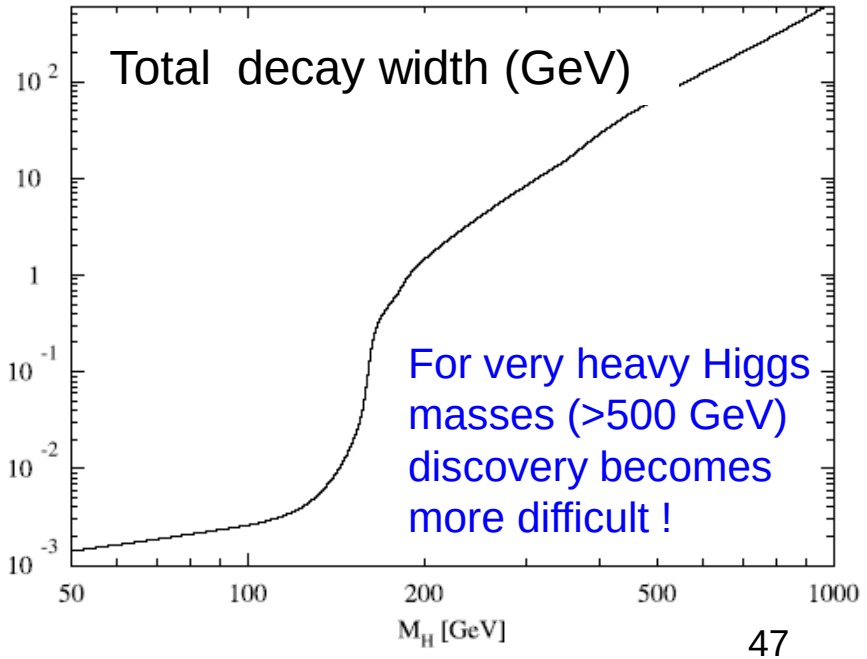
$$\Gamma(H \to f\bar{f}) = N_c \frac{G_F m_f^2 M_H}{4\pi\sqrt{2}} \times \left(\text{Kinematical Factor}\right)$$

Higgs couples preferentially to heaviest fermions

$$\Gamma(H \to WW, ZZ) \sim \frac{G_F M_H^3}{8\pi\sqrt{2}} \times \left(\text{Kinematical Factor}\right)$$

… or to heavy bosons: at LEP not accessible!



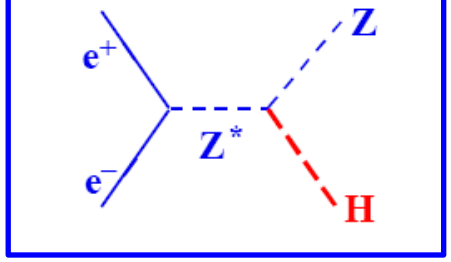


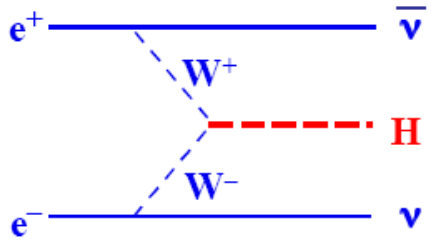
5.1 Direct Higgs search at LEP

$$\Gamma(H \to f\bar{f}) \sim \frac{G_F m_f^2 M_H}{4\pi\sqrt{2}}$$

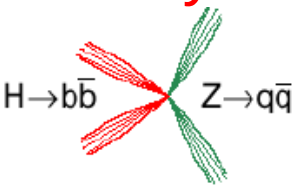
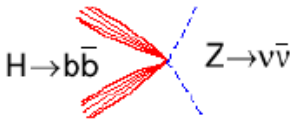
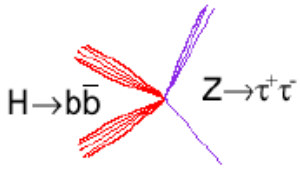
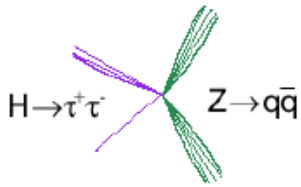
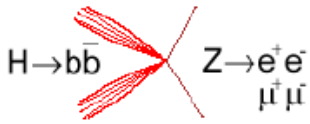
Production

Higgs bremsstrahlung





Decay

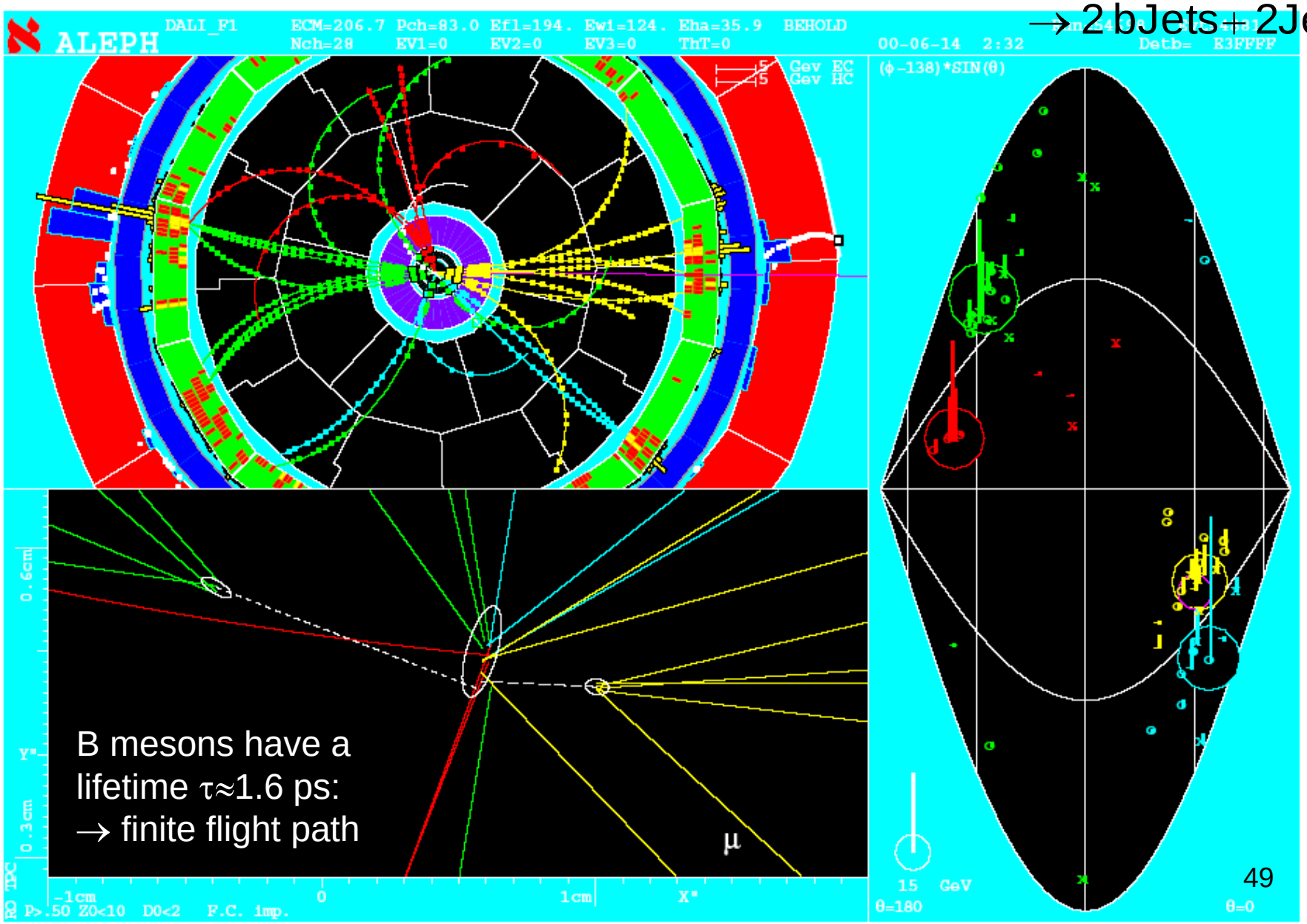
			Main background:
	**4-Jet-Kanal**	51%	WW→qqqq,ZZ→bbqq QCD 4jets
	**Neutrino-Kanal**	15%	WW→qqlν,ZZ→bbνν
	**Tau-Kanal**	2.4%	WW→qqτν,ZZ→qqττ QCD (low-mult. jets)
		5.1%	
	**Lepton-Kanal**	4.9%	ZZ→bbll

Higgs bremsstrahlung is dominant production process at LEP: **m_H – Limit = $\sqrt{s}$ - m_Z**

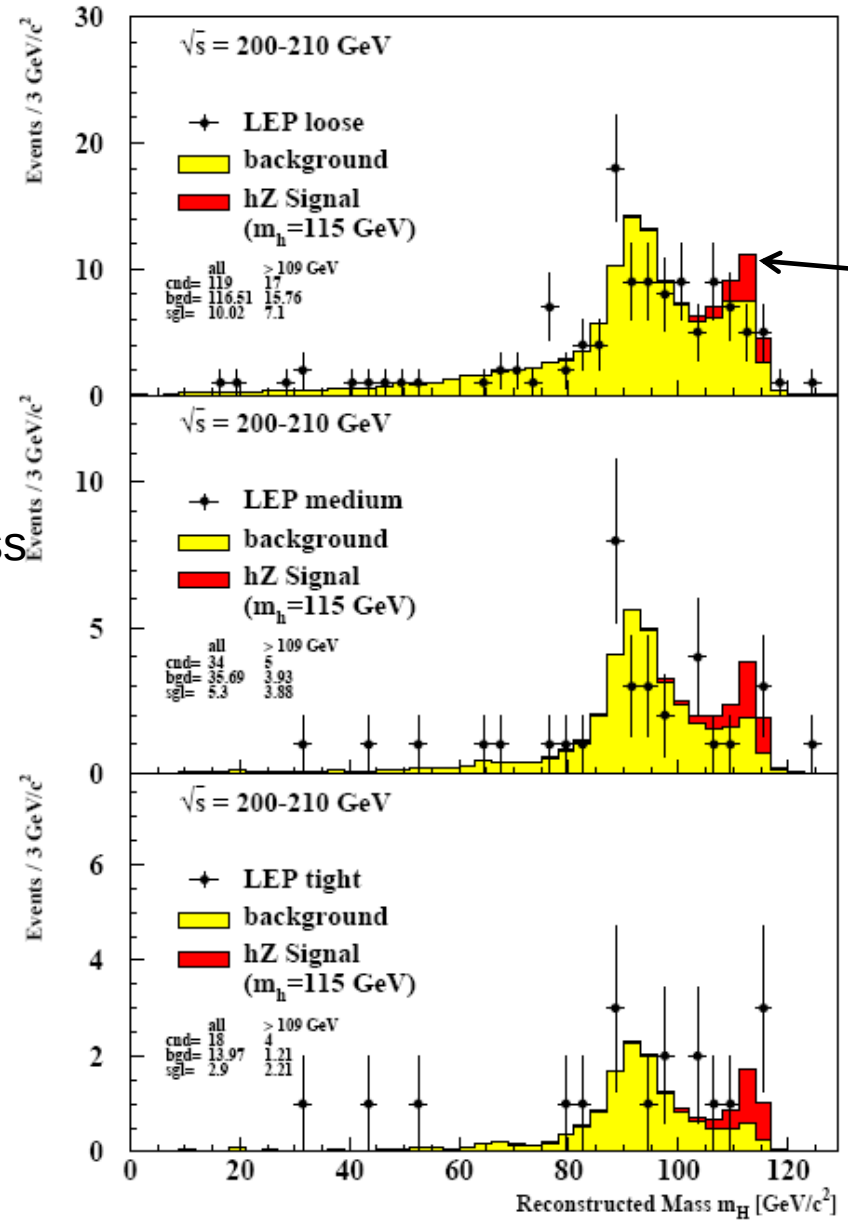
Higgs search at LEP includes 80% of the final states, selection efficiency ~40 - 50%

Higgs candidate with M_H=114 GeV ? $e^+e^- \rightarrow H(b\bar{b})Z(q\bar{q})$

$\rightarrow$ 2 bJets + 2Jets



Invariant mass of LEP Higgs candidates



Tightness of cuts

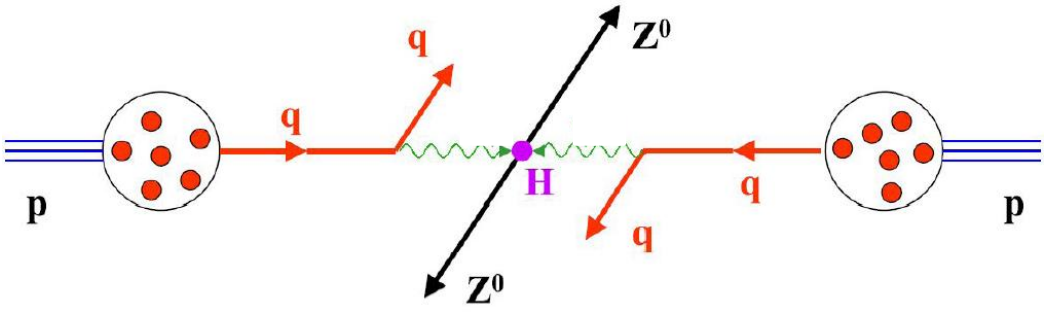
Expected Higgs signal for $m_h = 115$ GeV

No signal above background seen

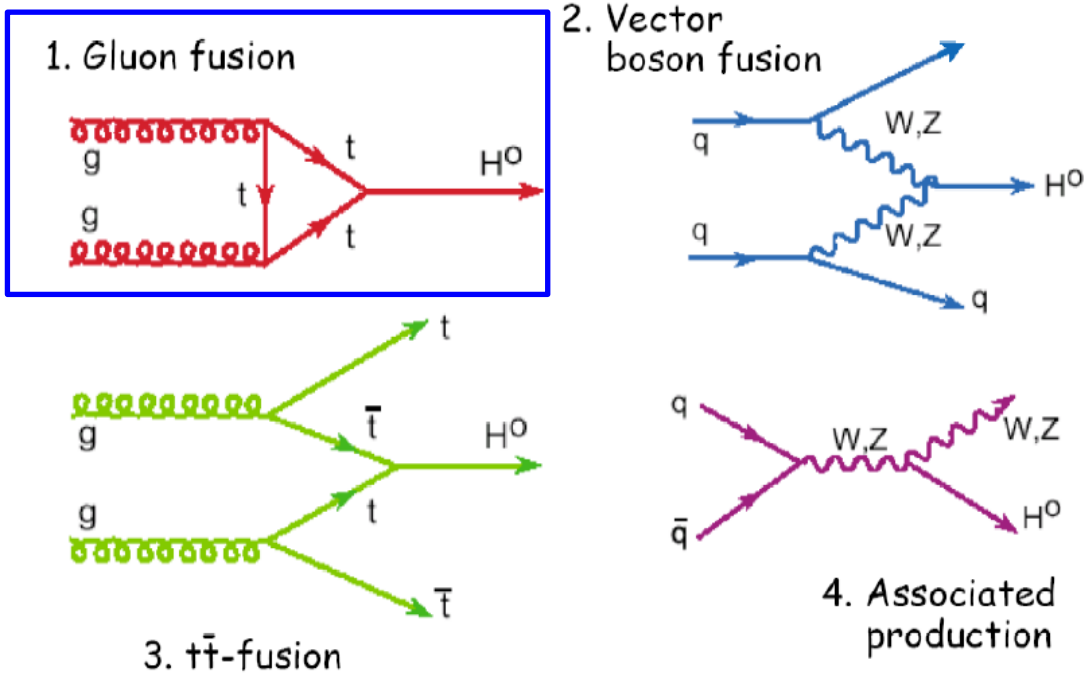
LEP excludes a 114.4 GeV Higgs boson @ 95% CL.

Higgs-Limit:
(200…210) GeV – m_Z = 114.4 GeV

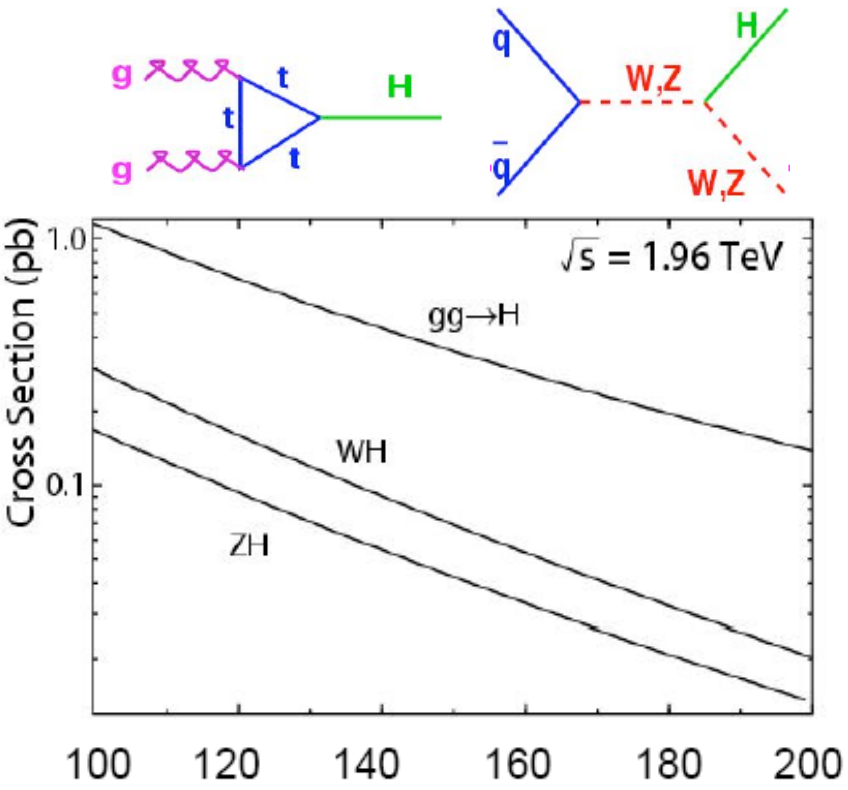
5.2 Higgs production at pp(-) collider



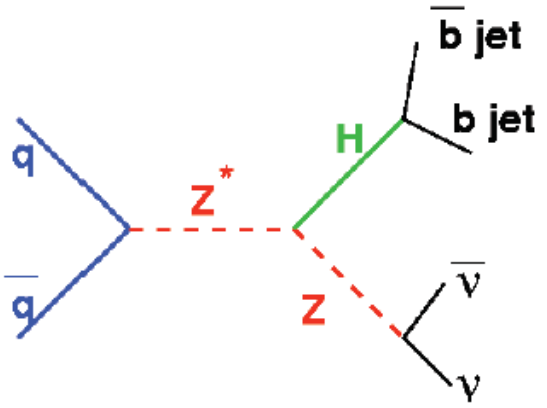
Dominant at LHC

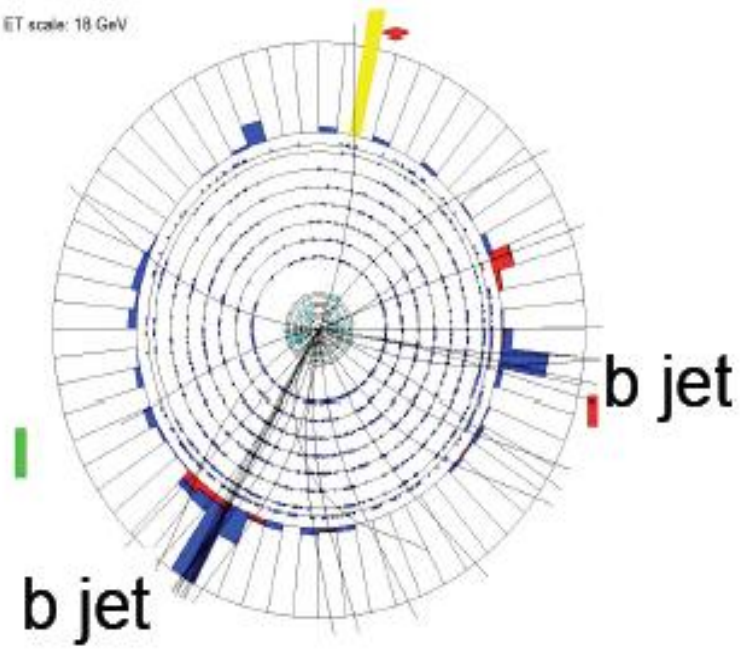


Higgs Search at the Tevatron



~1 Higgs event every 10^{12} events

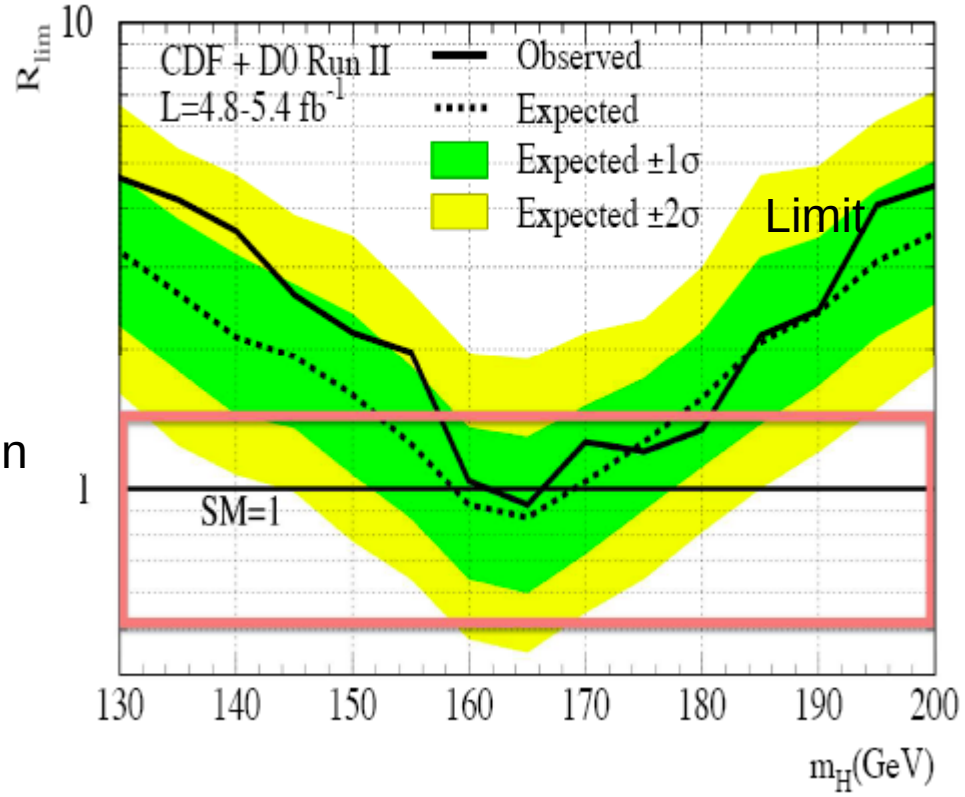




Higgs Search at TEVATRON

Many different decay channels analyzed: $ZH \to \ell^+\ell^- b\bar{b}$ $H \to W^+W^-, \gamma\gamma$

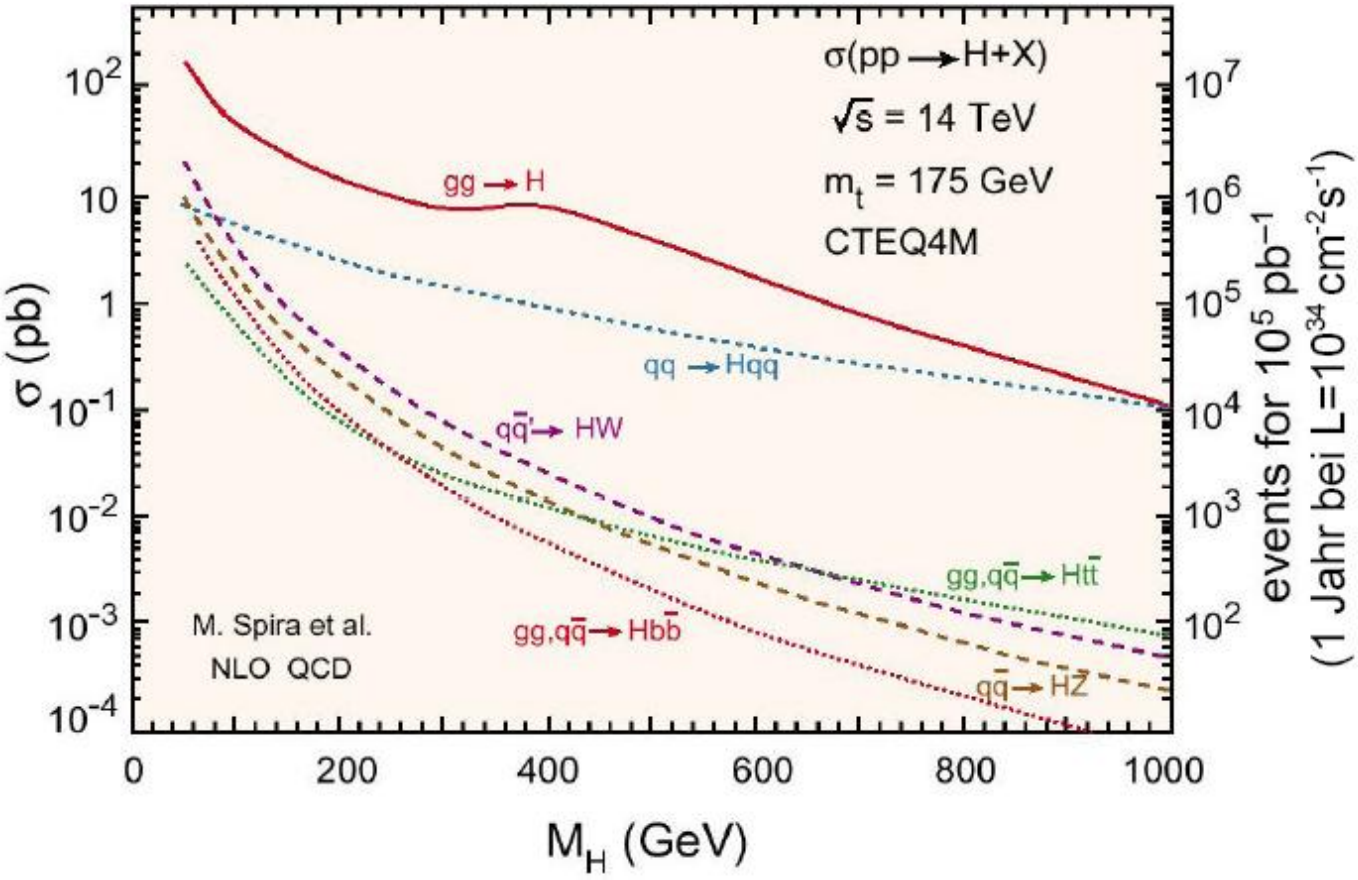
Moriond 2010



Limit R_{Lim} expressed expressed in $SM_{expectation}$

Higgs production at the LHC (plan/now: pp at 14 / 7 TeV)

- $p + p \rightarrow H + X$



The lower CM energy of LHC severely cuts into the Higgs discovery potential.

Higgs decay channels

At LEP: Searches were done using

$H \to b\bar{b}$ $M_H > 114$ GeV

At TEVATRON:

$ZH \to \ell^+\ell^- b\bar{b}$

$H \to W^+W^-, \gamma\gamma$

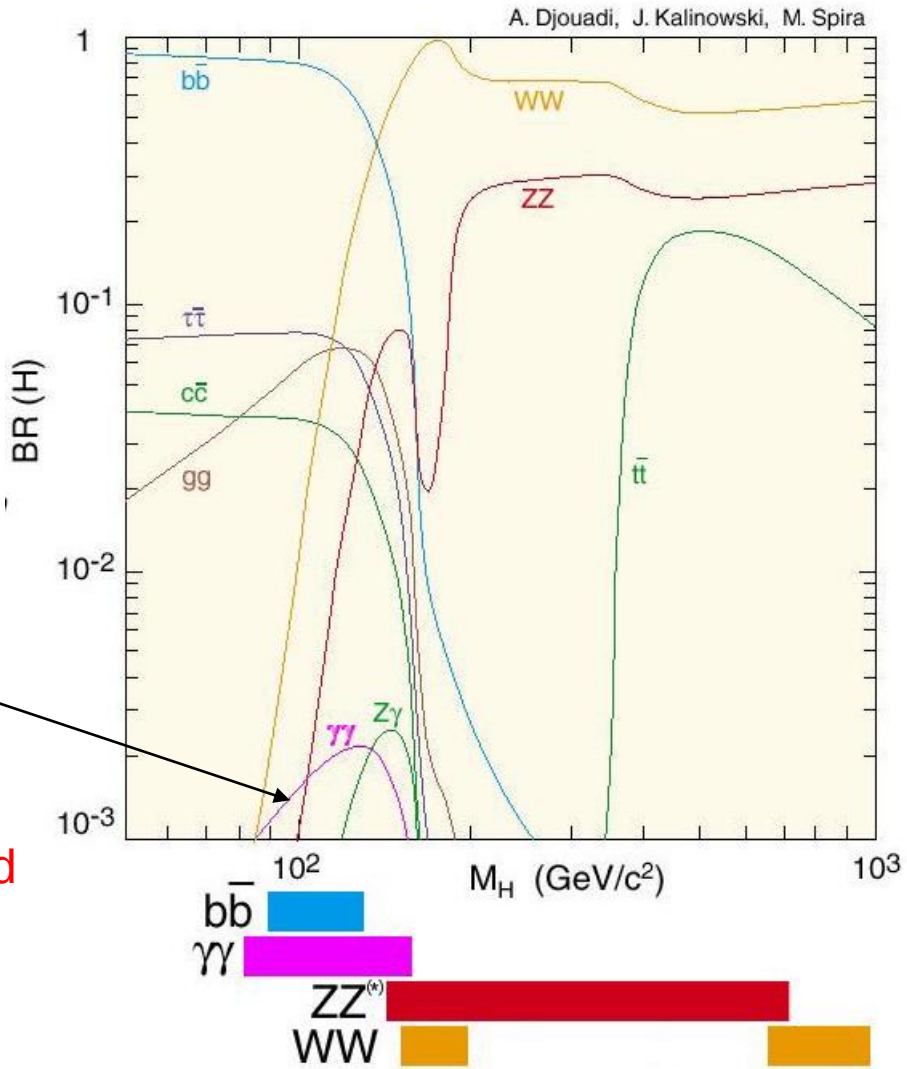
At LHC:

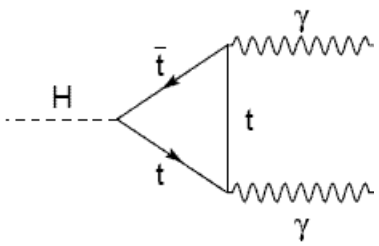
- $m_H < 150$ GeV: $H \to \gamma\gamma$
- 150 GeV < m_H < 1 TeV

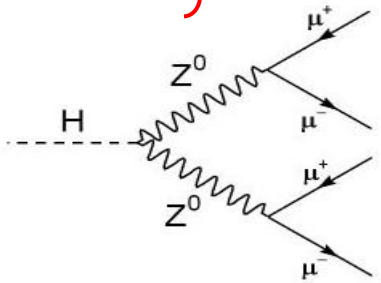
$H \to ZZ^{(*)}$

$H \to W^+W^-$

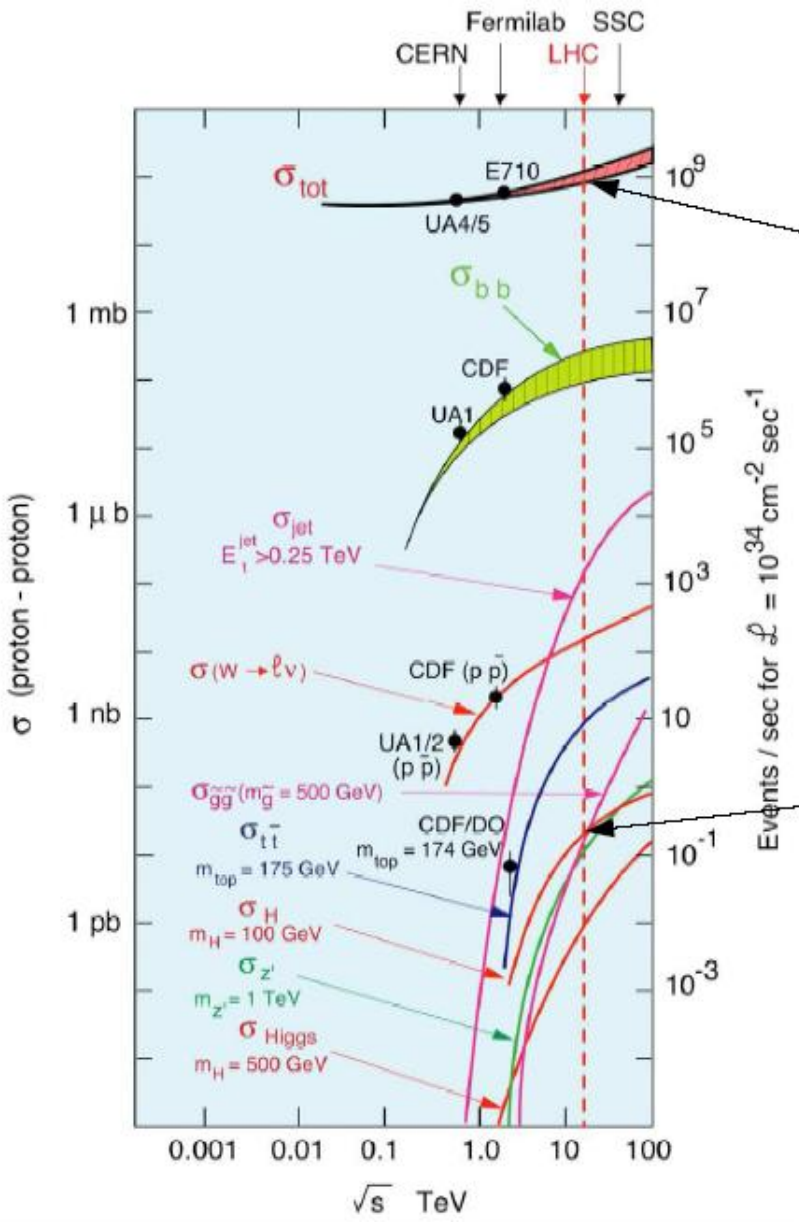
Mass region excluded







The Challenge: Triggering the Higgs-Events



Trigger @ LHC

10^9 events/sec

10^{10} rate reduction

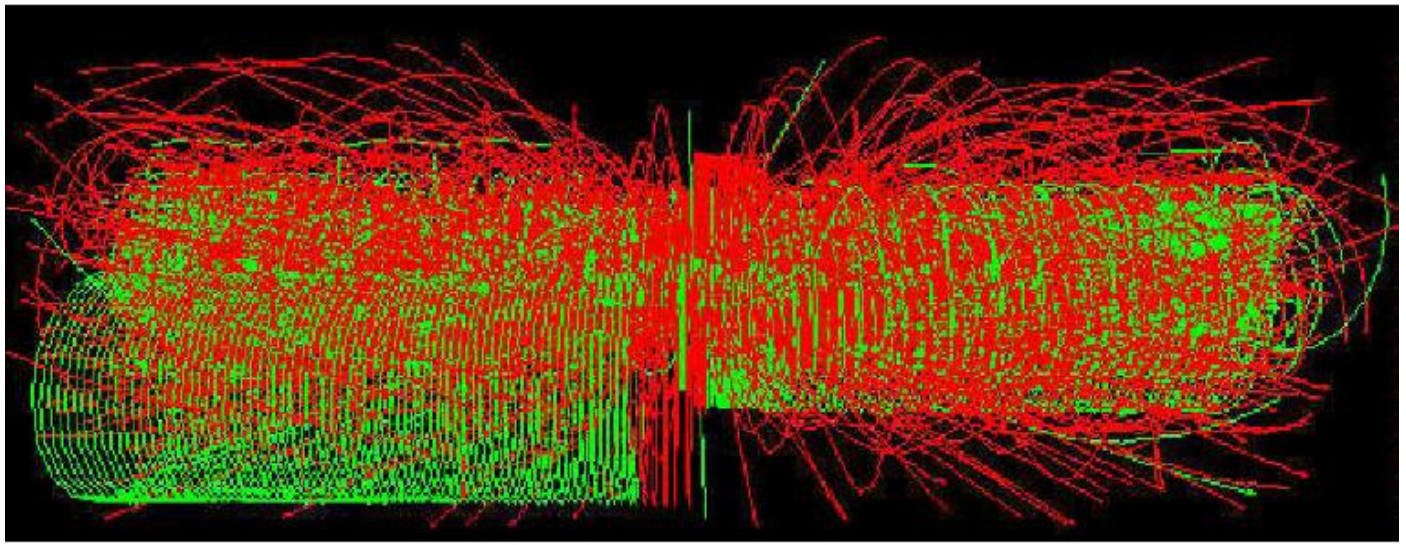
10 events/min
[M_H = 100 GeV]

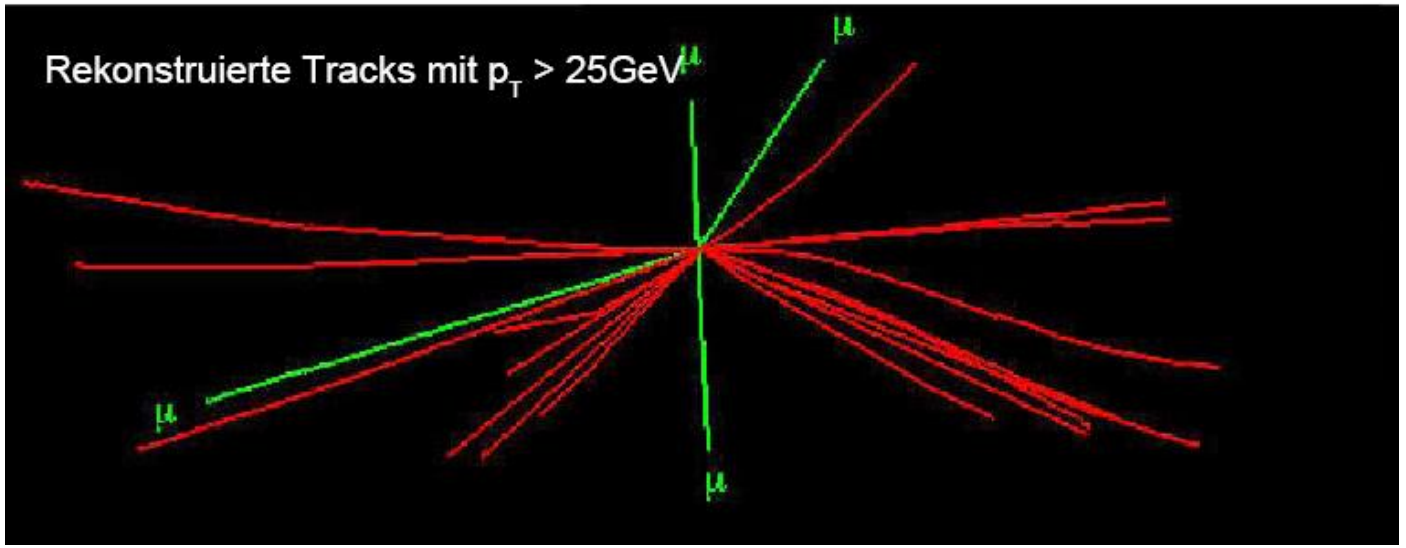
with 0.2% $H \to \gamma\gamma$
1.5% $H \to ZZ$

At design luminosity of 10^{34} cm^{-2}s^{-1} and design energy!

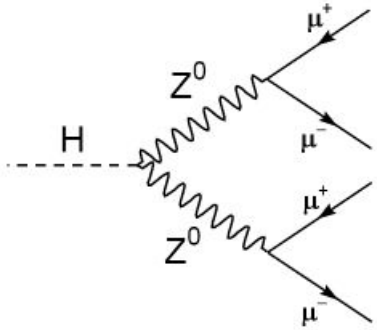
Simulated H→ZZ→4μ event at LHC

- 20 pp interaction / beam crossing
- Very large number of particles





"Golden" channel easy!

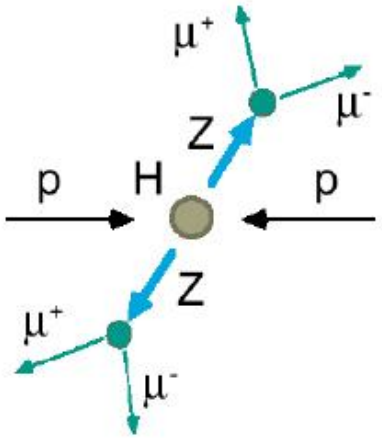


To trigger and to reconstruct these events is an exp. challenge.

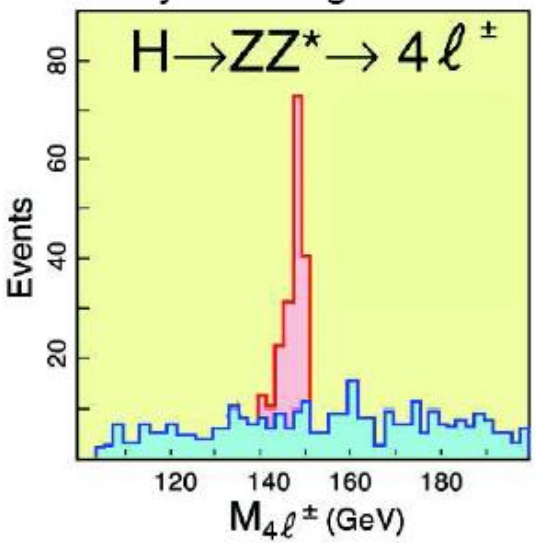
“Golden” Higss decay channel: H → ZZ → μμ μμ

Discovery potential:
130 – 600 GeV

4 leptons p_T > 20 GeV



Very clean signal

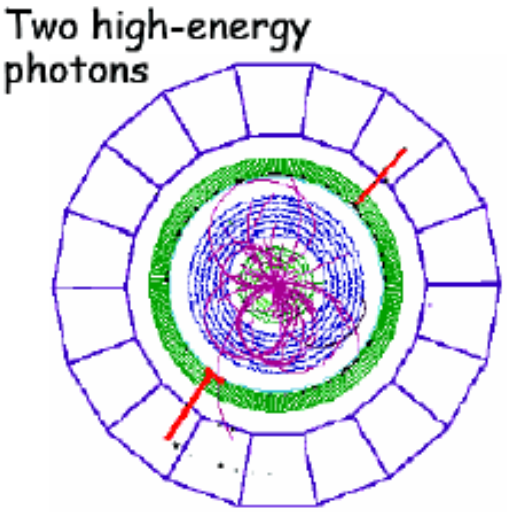


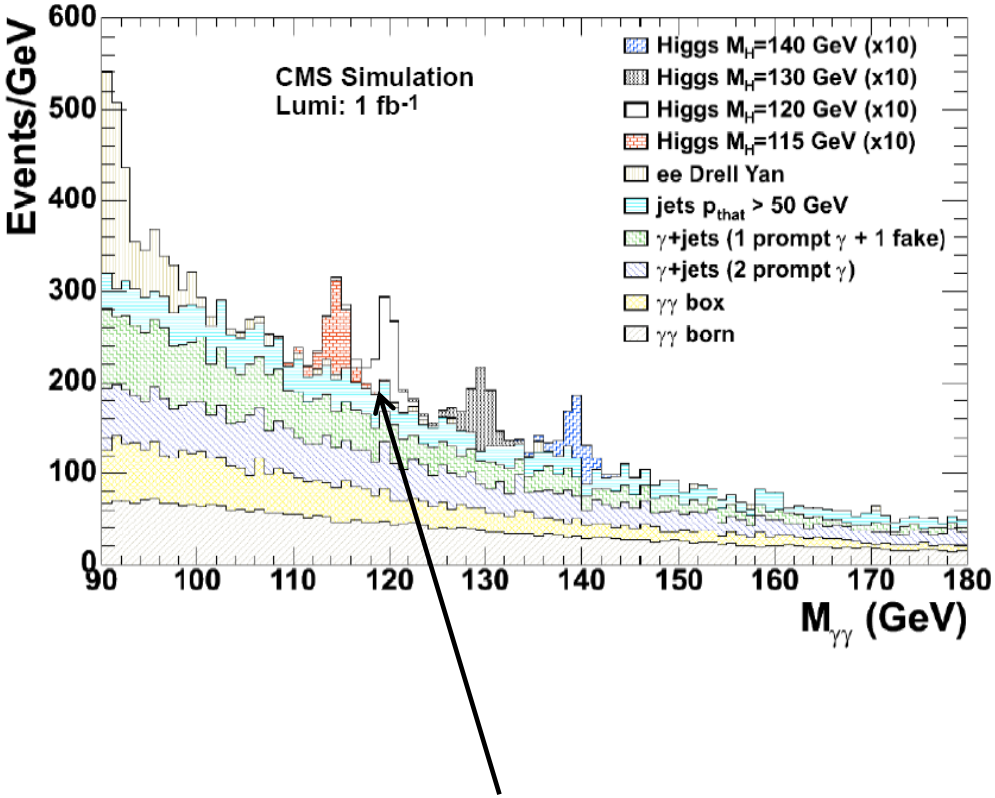
Backgrounds:

- *tt –> Wb Wb –> lν clν lν clν*
- *Z bb –> l l clν clν*
- *continuum ZZ*

A Higgs in the above mass region has a high probability to be discovered with the data of the coming LHC year … but if we believe the indirect constraints it is rather unlikely!

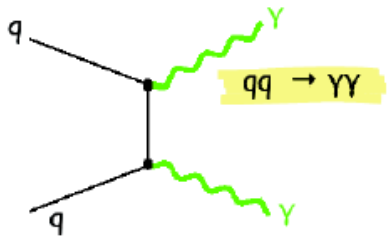
More challenging: Higgs search: $H \rightarrow \gamma\gamma$

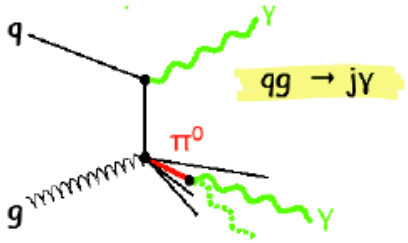




Large backgrounds:

- 2γ production: irreducible background
- γj and jj production: reducible background
  jet rejection of > 10^3 is required



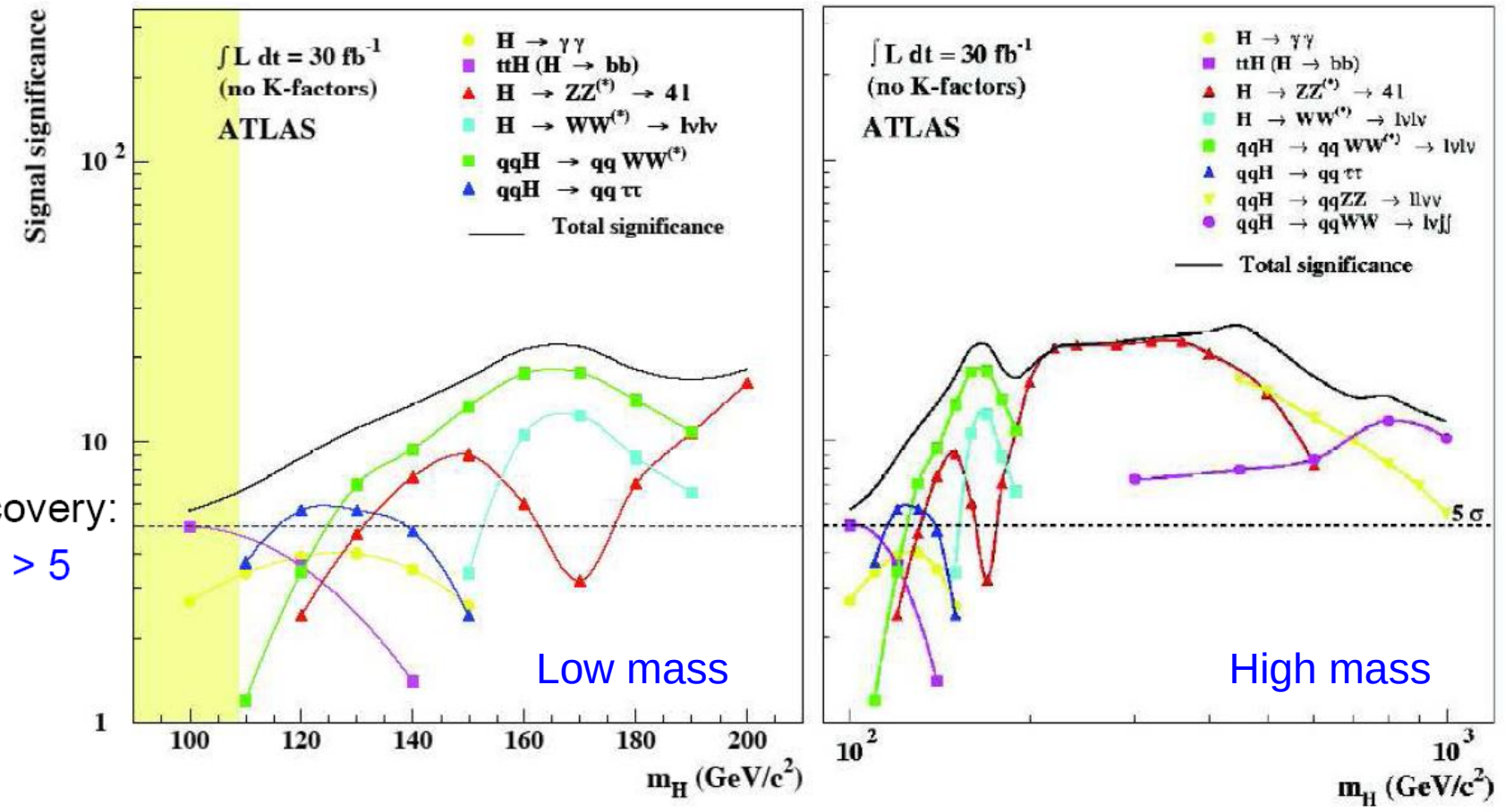


Signal shown scaled with factor x10!

demands excellent calorimetry

LHC Higgs discovery potential

Signal significance: $S = \frac{N_{\text{signal}}}{\sqrt{N_{\text{bg}}}} = \frac{N_{\text{tot}} - N_{\text{bg}}}{\sqrt{N_{\text{bg}}}}$



Discovery:
$S > 5$

Low mass region is not easy – demands combination of several channels

If the Higgs exists it will be found at the LHC … but it might take a while!