The elusive agent of electroweak symmetry breaking - an experimentalist point of view -

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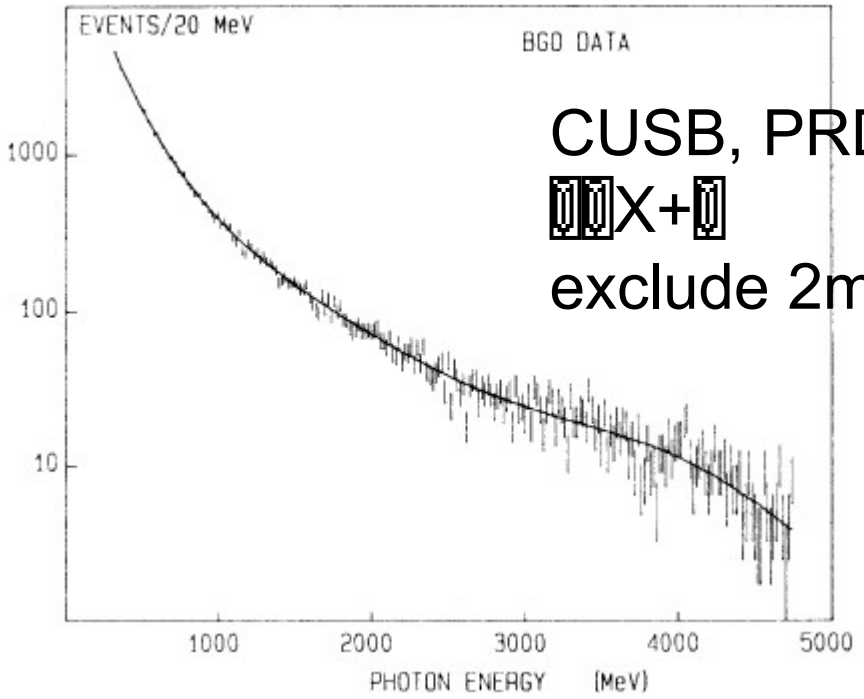
Brown University

the holy grail of particle physics

H searches before LEP

experiments at PSI, SPS, CESR



CUSB, PRD 35, 2883 (1987)

□□X+□

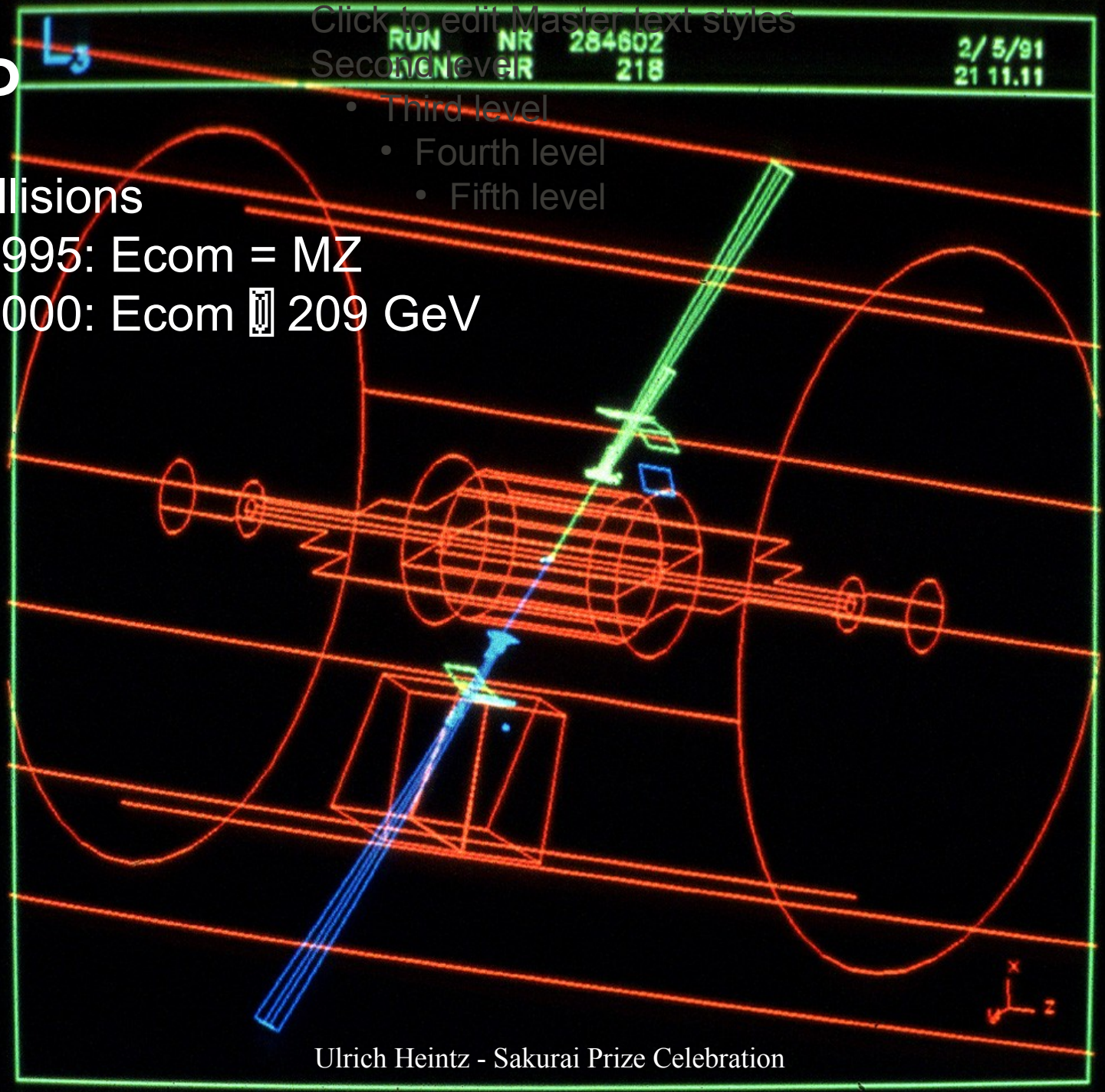
exclude 2m□ < mH < 5 GeV

excluded $m_H < 5$ GeV

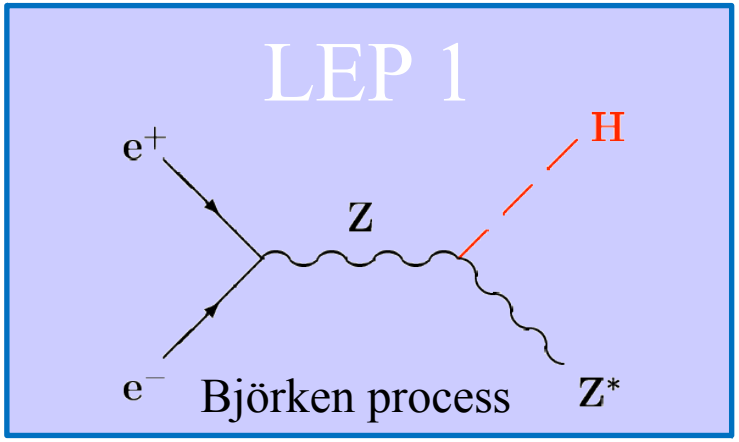
subject to significant uncertainties

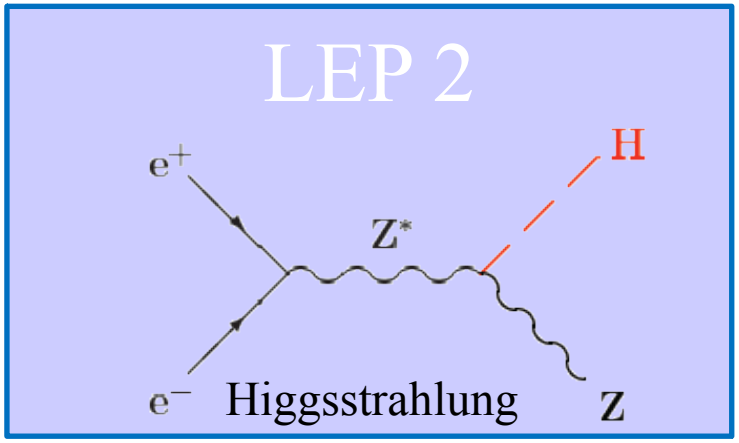
LEP

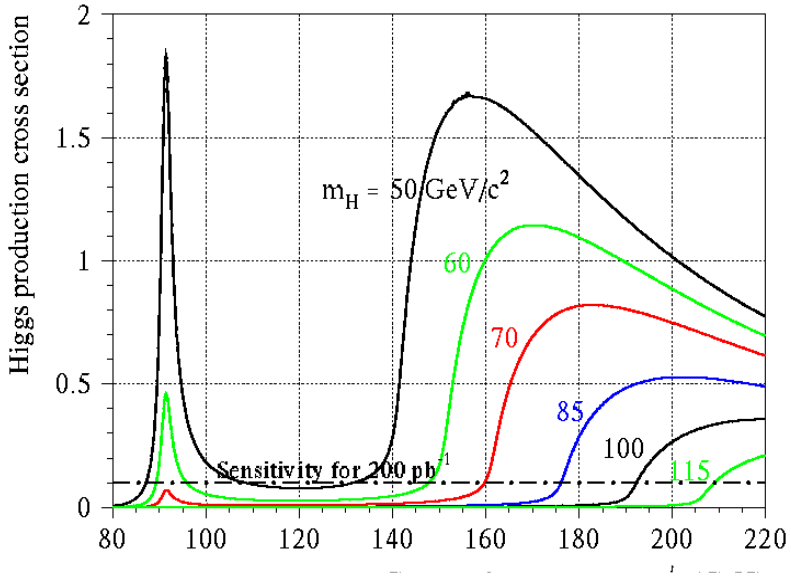
e+ẽ collisions
1989-1995: Ecom = MZ
1996-2000: Ecom ≥ 209 GeV



H production at LEP



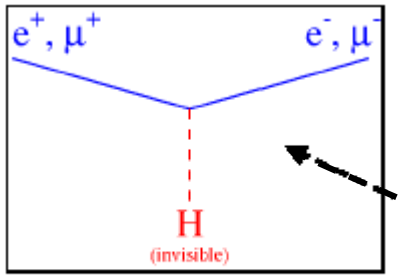




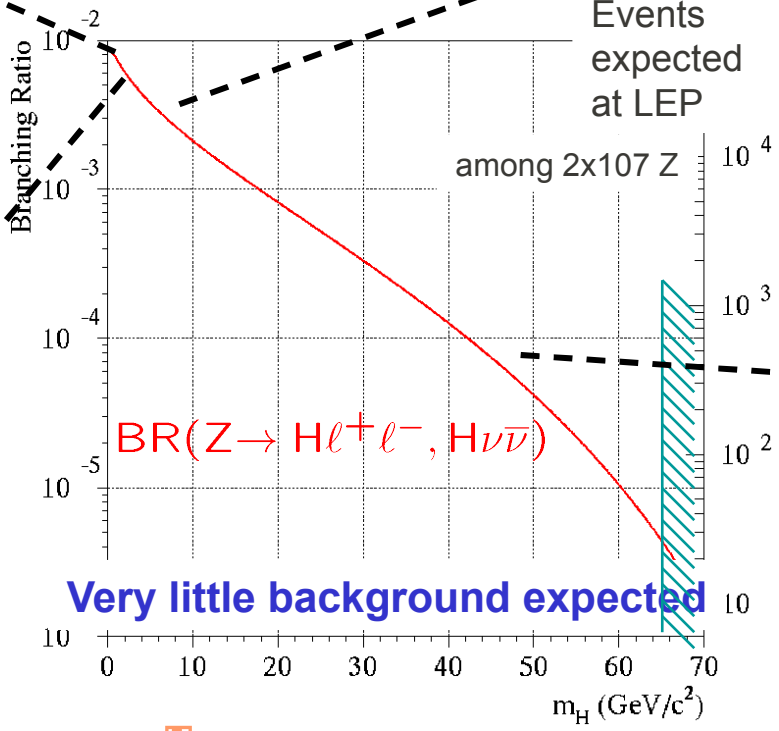
H search at LEP1

0.0 ≤ mH ≤ 65 GeV/c2

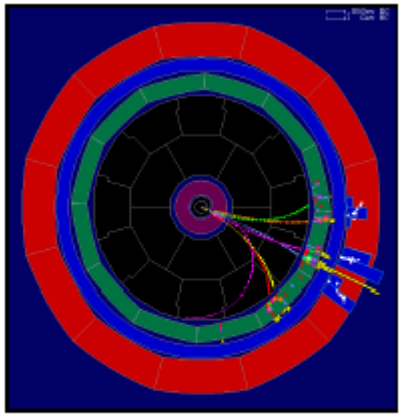
Excluded at 95% C.L.



Acoplanar lepton pairs

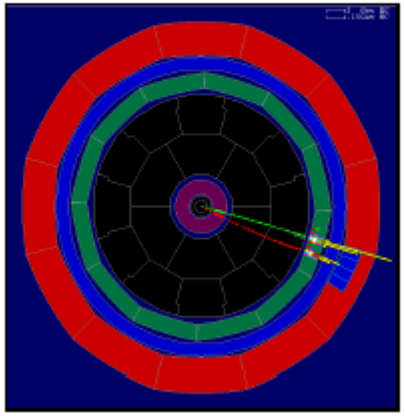


*for **mH<2mb**:*
H → gg, cc, ...



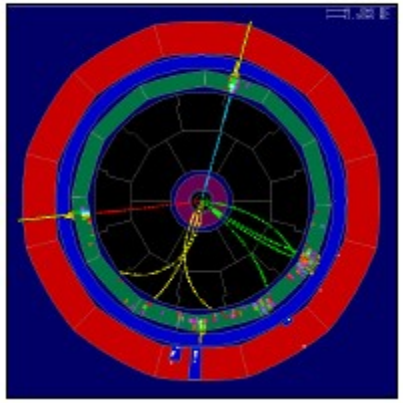
Monojets

Acoplanar pairs



*for **mH<2mℓ** :*
H → ee, ...

Acoplanar jets

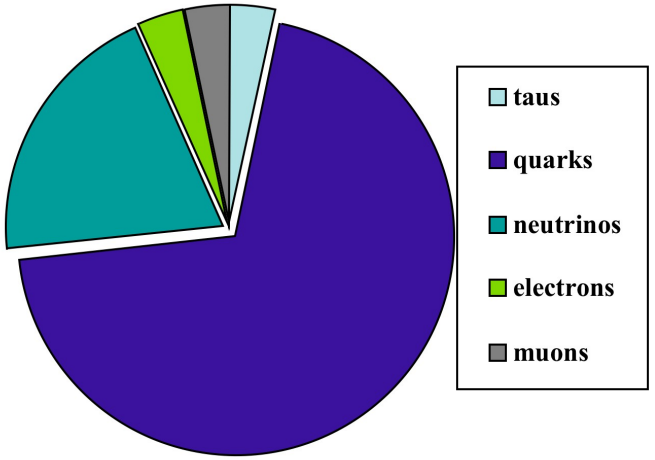


*for **mH<2mW** :*
H → bb (~80%)

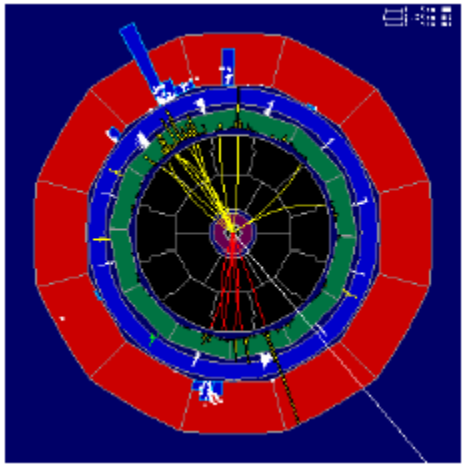
H searches at LEP2

Decay signature defined by Z decay

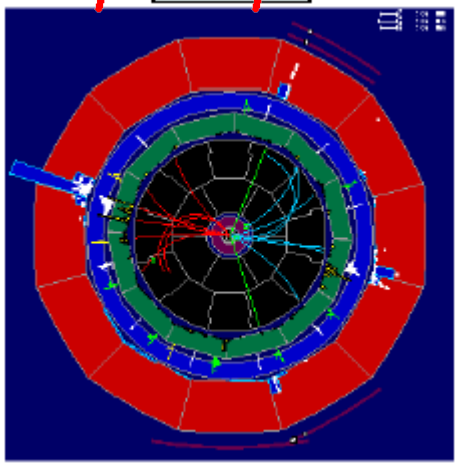
Higgs	Z	Fraction
bb	qq	51.5%
bb	νν	14.7%
Any	ll	6.7%
bb	ττ	2.5%
ττ	qq	5.0%
Total		80.9%



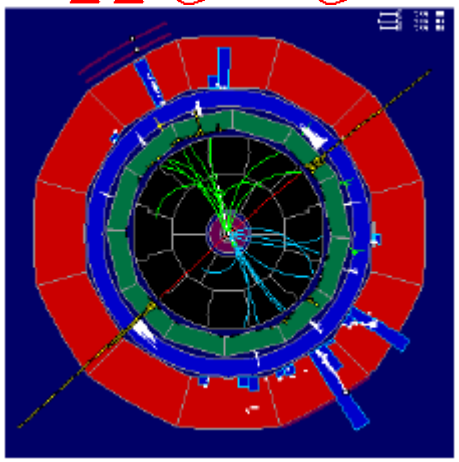
"missing E" $H\nu\bar{\nu}$



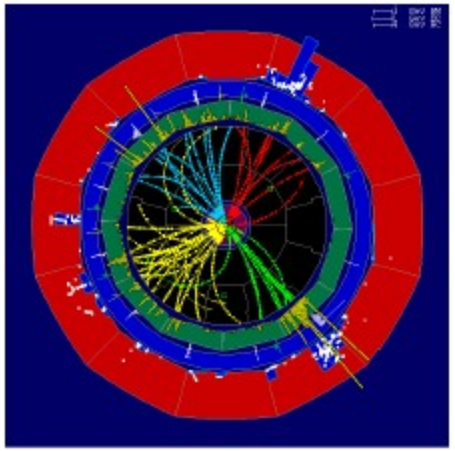
"leptons" $H\mu^+\mu^-$



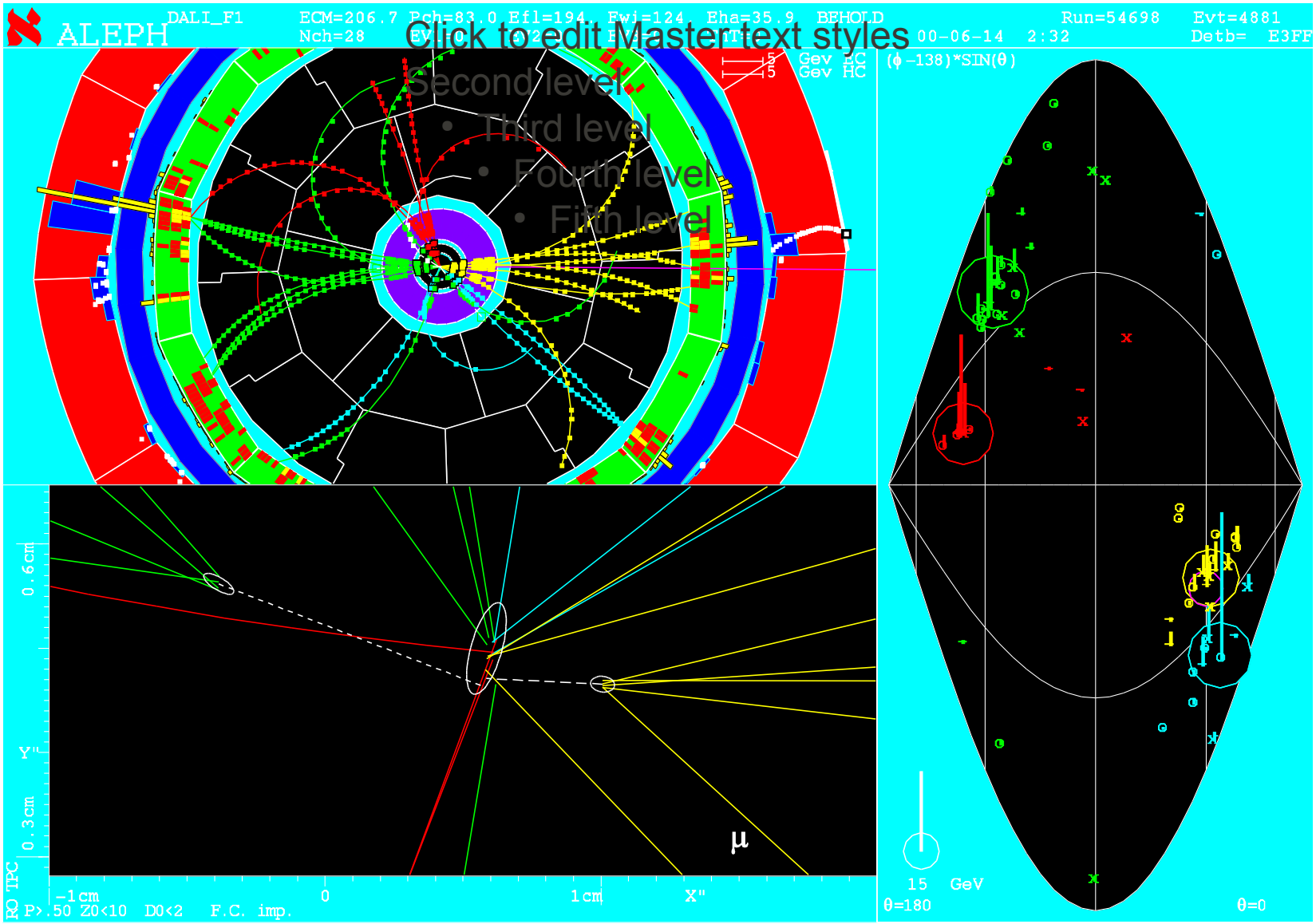
He^+e^-



"4-jets" $Hb\bar{b}$



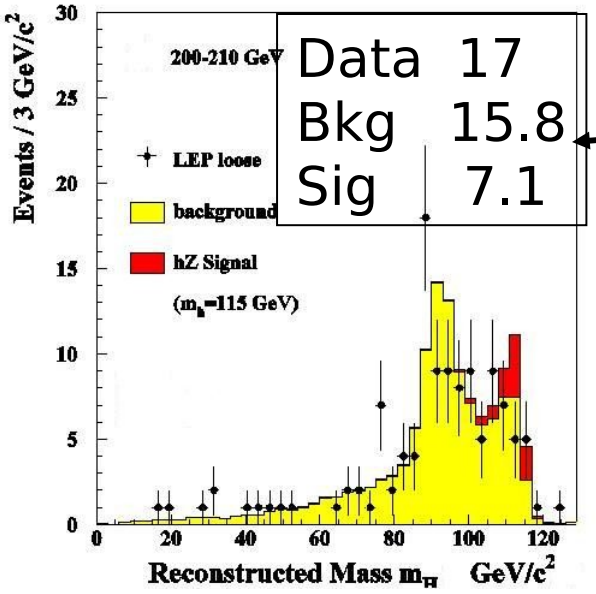
and then…

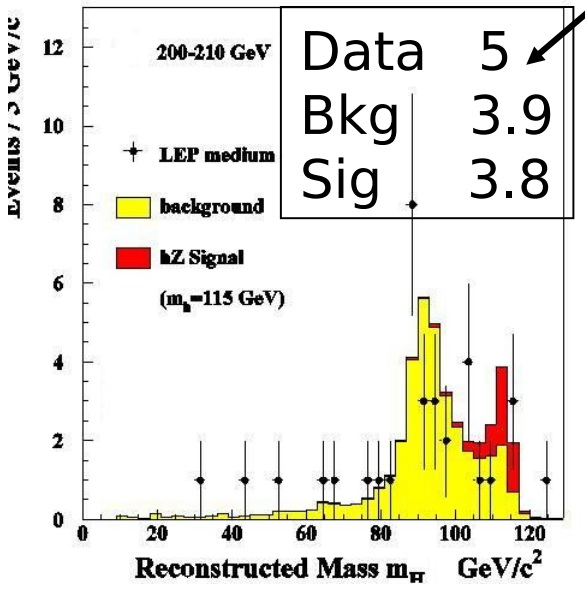

ALEPH
DALI_F1
ECM=206.7 Pch=83.0 Efl=194 Ewi=124 Eha=35.9 BEHOLD
Nch=28
Run=54698 Evt=4881
00-06-14 2:32
Detb= E3FF
Gev EC
Gev HC
(ϕ-138)*SIN(θ)
0.6cm
0.3cm
Y"
-1cm
0
1cm
X"
RO TPC
P>.50 Z0<10 D0<2 F.C. imp.
μ
15 GeV
θ=180
θ=0

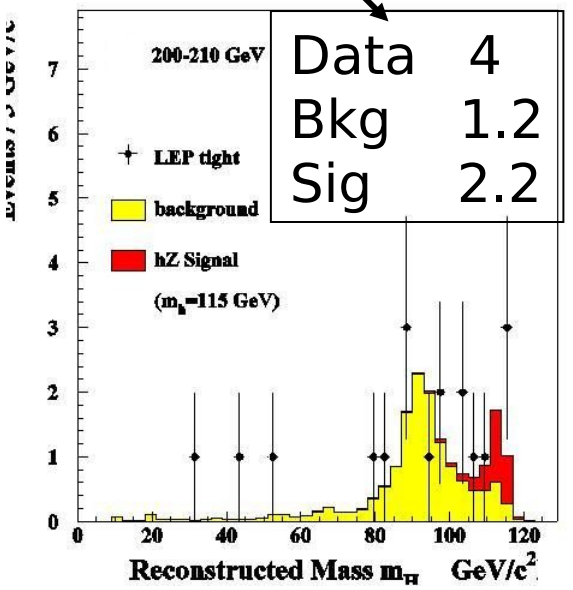
discovery or fluctuation?

3 selections with increasing purity for mH = 115 GeV

S/B for mH > 109 GeV/c2
> 0.5 >1 >2







"the results of the experiment were inconclusive so we had to use statistics..."

the final LEP limit

modified frequentist confidence levels

define likelihood ratio

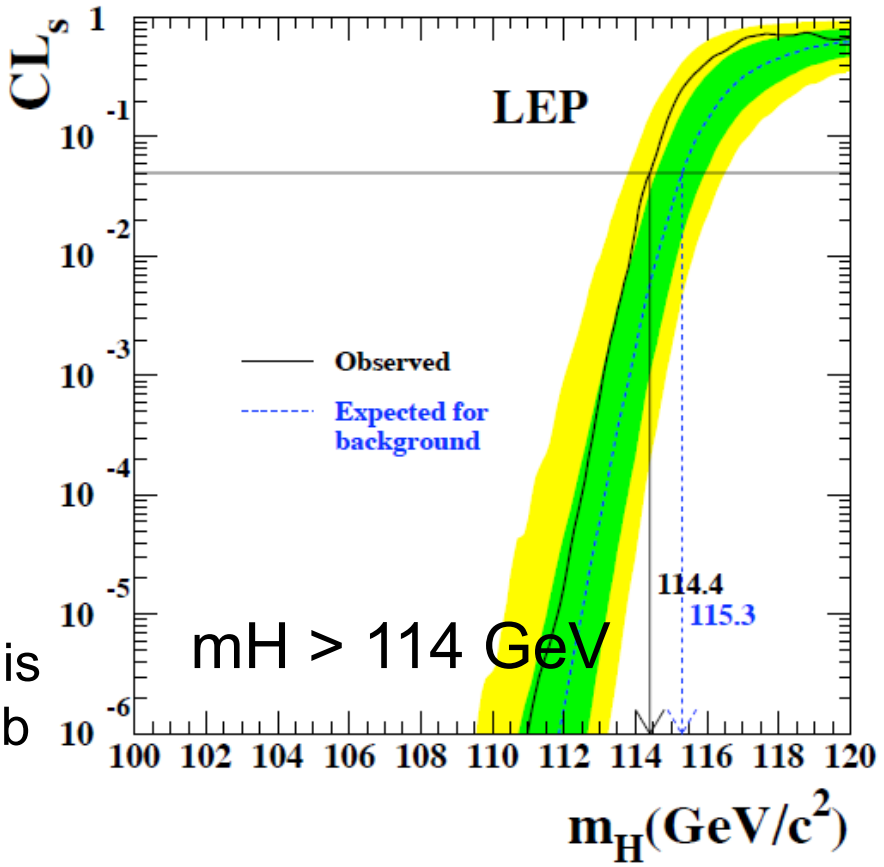
$$L = \frac{p(data \mid s+b)}{p(data \mid b)}$$

$CL_b = P(L \le L_{obs})$ for background

$CL_{s+b} = P(L \le L_{obs})$ signal + background

$$CL_s = \frac{CL_{s+b}}{CL_b}$$

how much less likely is observed data for s+b than for b only?



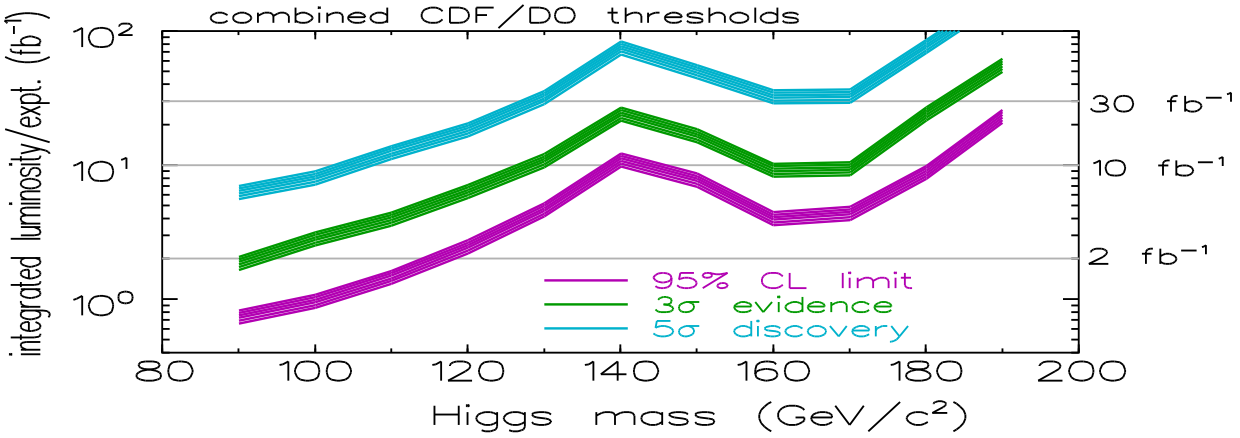
Signal can be excluded at 95% CL if CLs < 0.05

the end of LEP

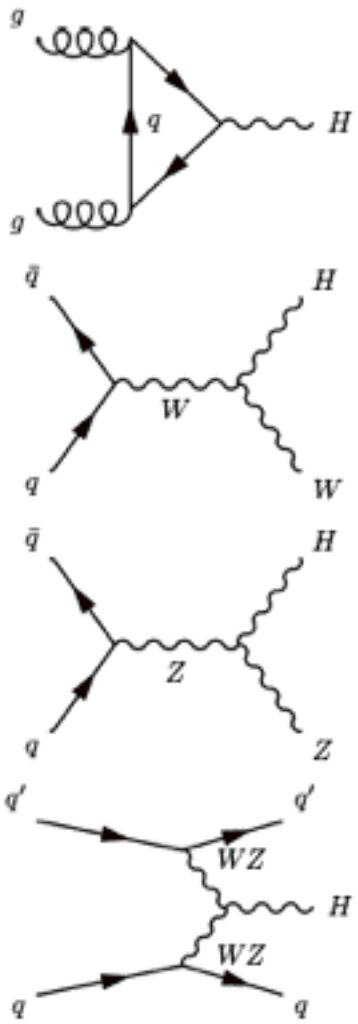
Tevatron

- pp collisions
  Ecom = 2 TeV
  L = 4×1032/cm2/s (2 fb-1/year)
  analyzed now: ∫Ldt = 5 fb-1
  expect ∫Ldt = 10 fb-1 by end of 2011

H at the Tevatron?



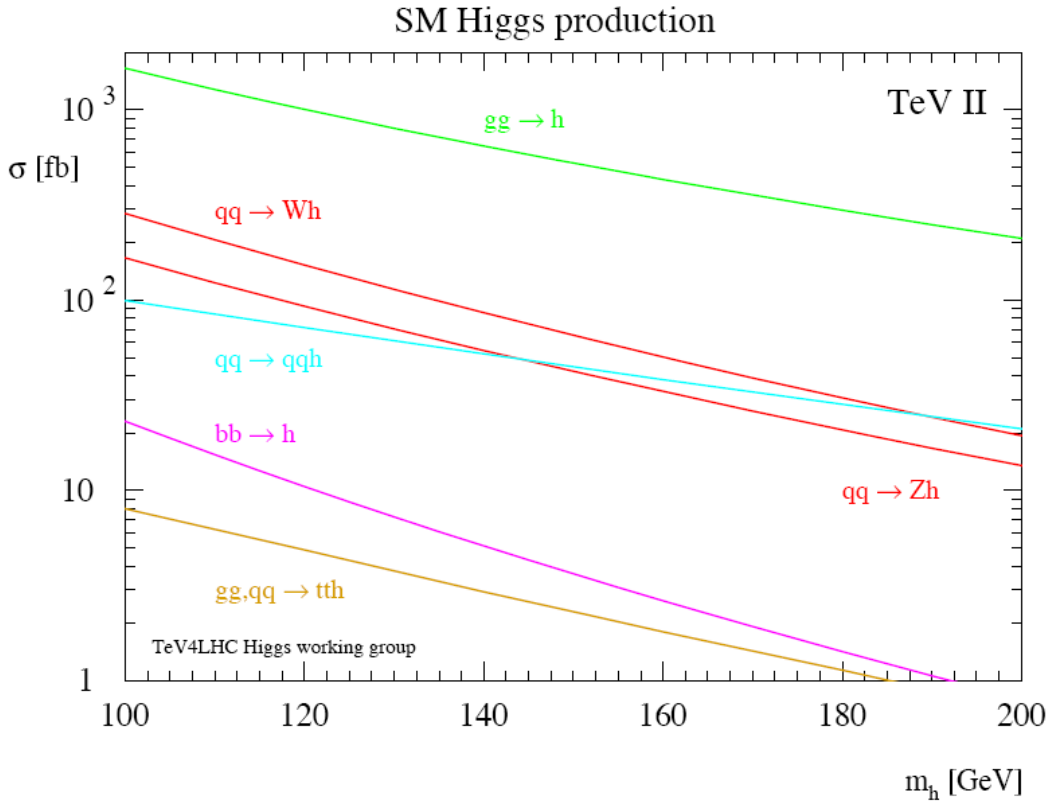
H production at Tevatron



gluon fusion 439 fb

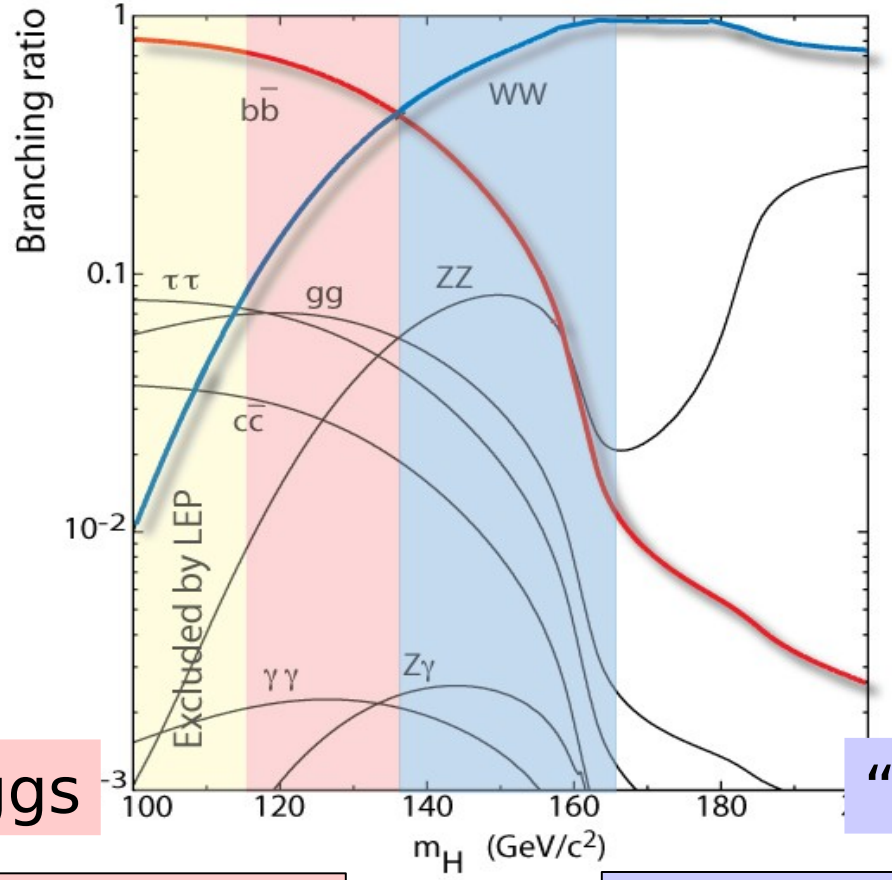
associate production WH: 51 fb ZH: 33 fb

vector boson fusion 39 fb



@MH=160 GeV

H search at Tevatron



"low mass" Higgs

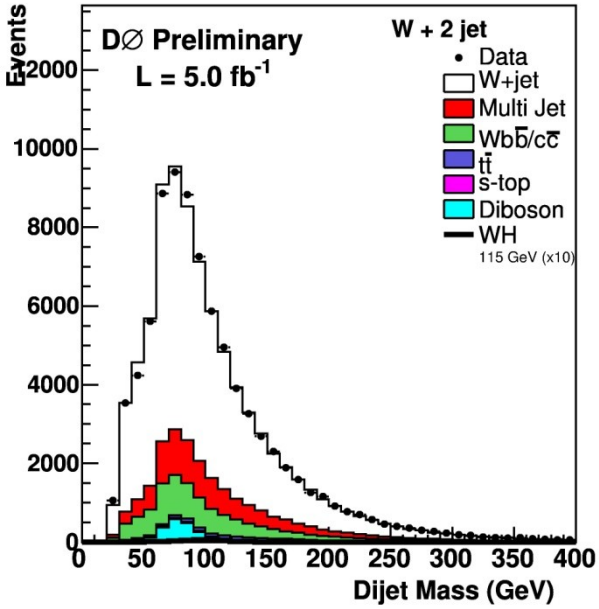
"high mass" Higgs

mH < 135 GeV (H→bb)
background driven
WH→lνbb, ZH→ll/νν bb

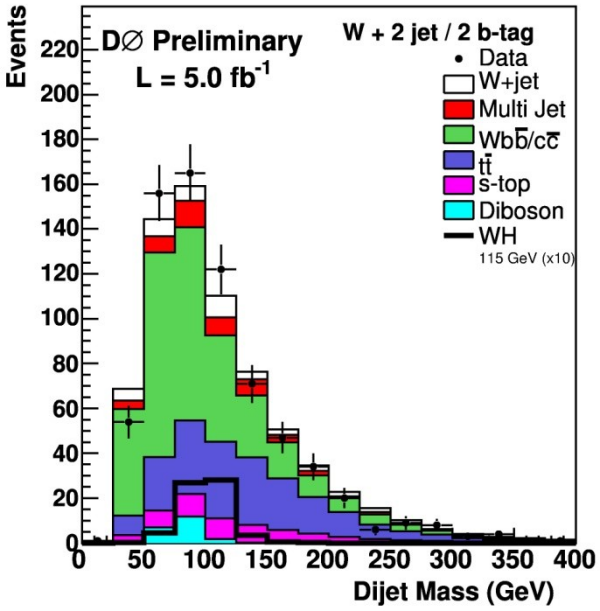
mH > 135 GeV (H→WW)
rate driven
all production modes

H search at Tevatron

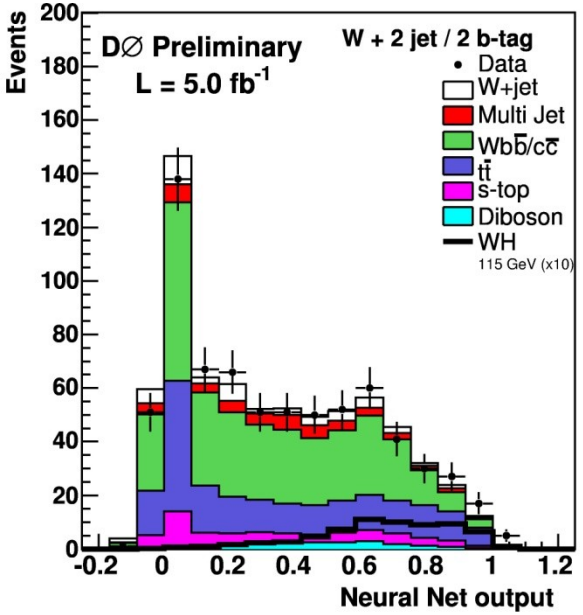
example channel: WH→lνbb



+ 2 b-tags



use several variables to form neural network discriminant

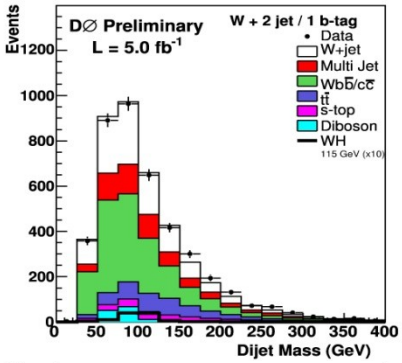


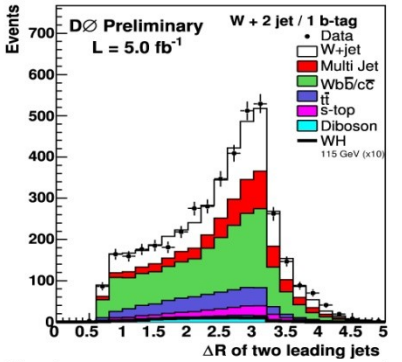
e/μ + $\not{p}_T$ + 2-3 jets
for mH = 115 GeV
expect 24 Higgs decays
in 84000 events

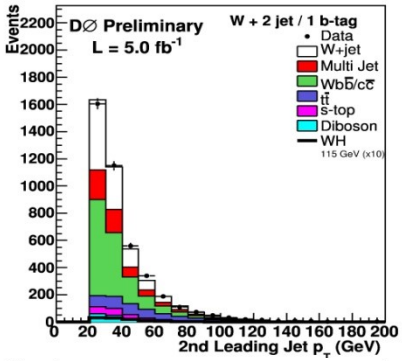
expect 7 Higgs decays
in 700 events

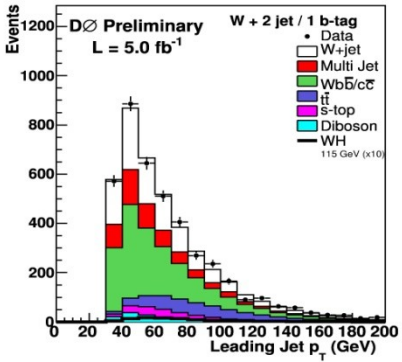
H search at Tevatron

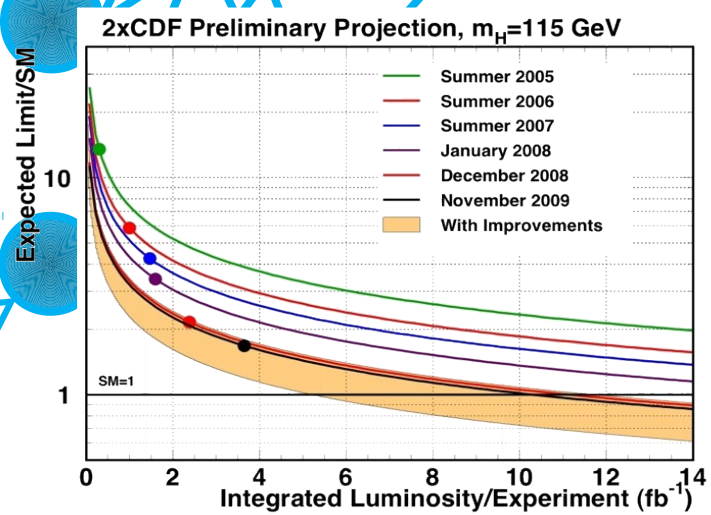
neural network

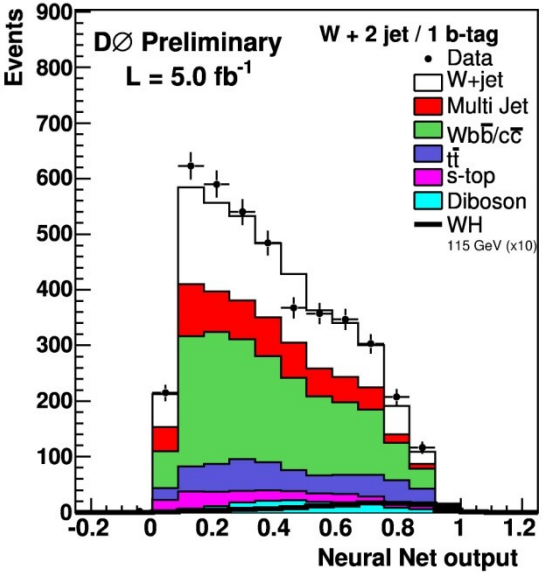








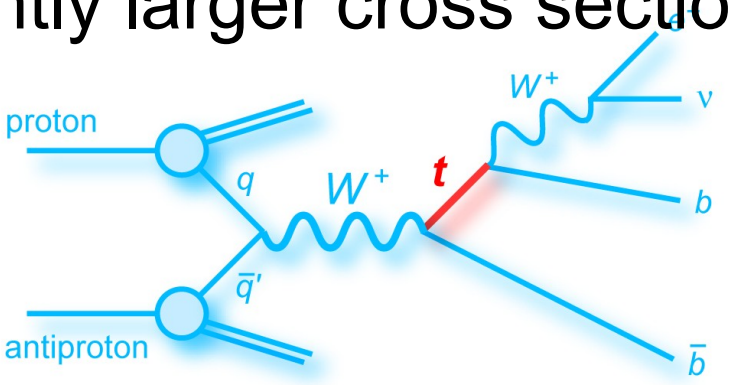


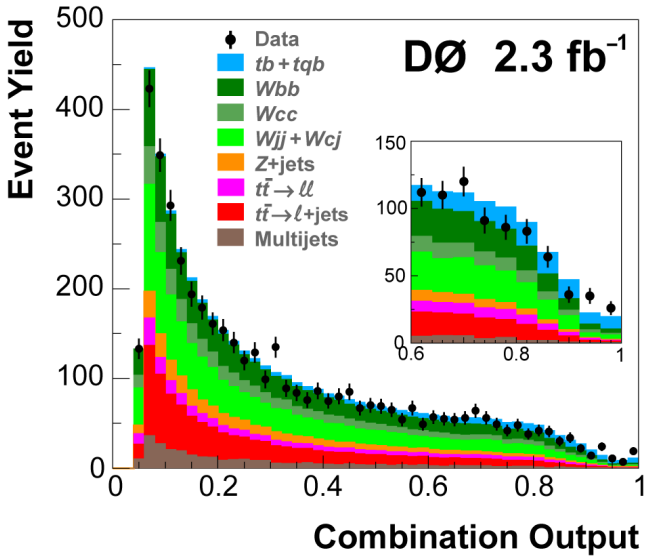


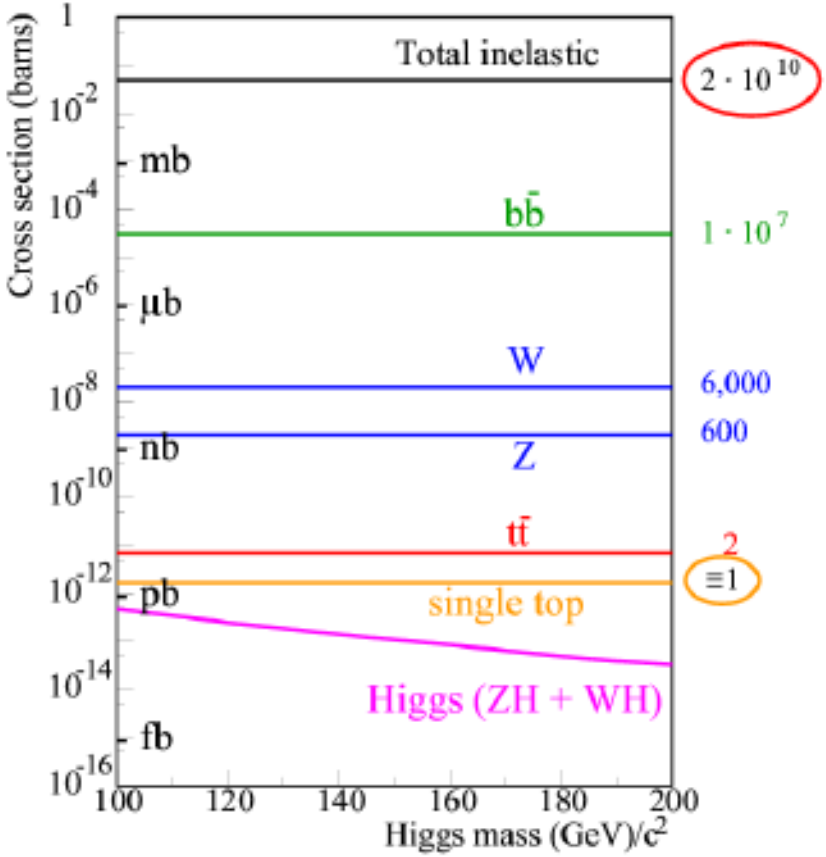
single top production

same final state as low mass Higgs

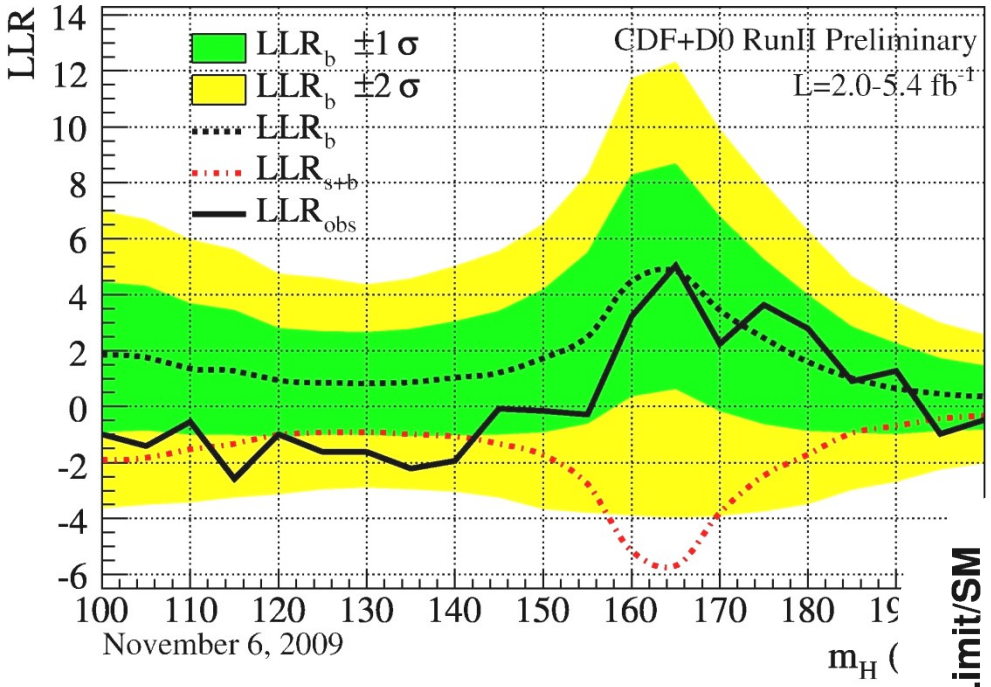
slightly larger cross section



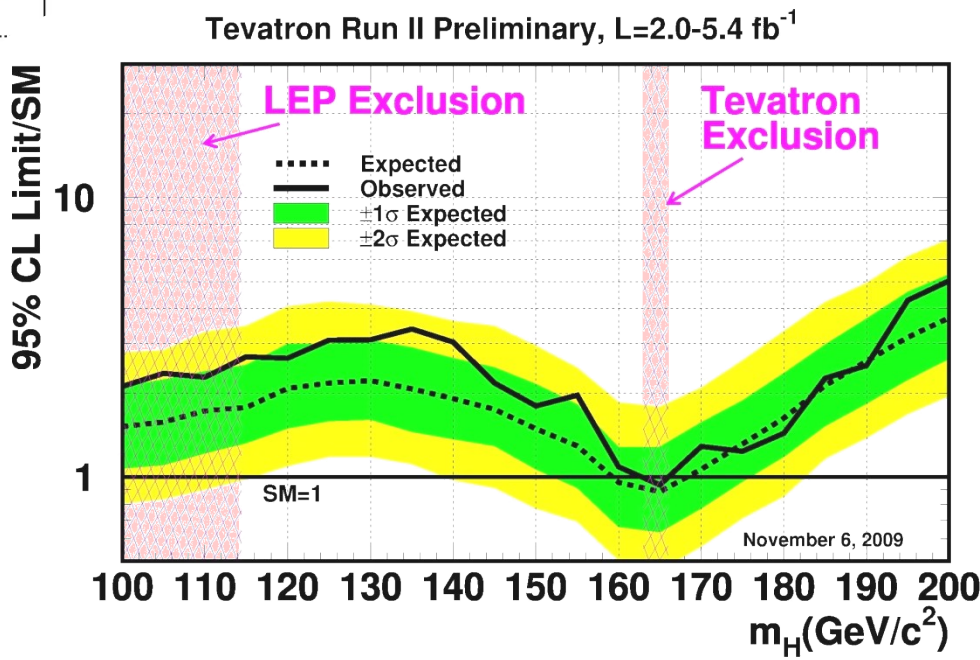




Tevatron H limits



published in
PRL 104, 061802 (2010)
by CDF and D0 Collaborations



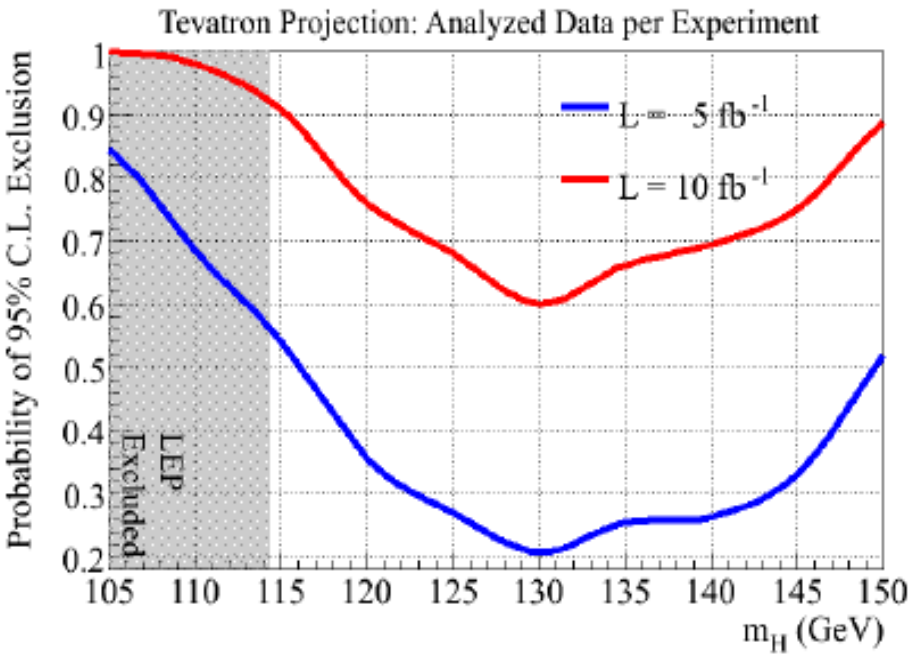
sensitivity of H search at Tevatron

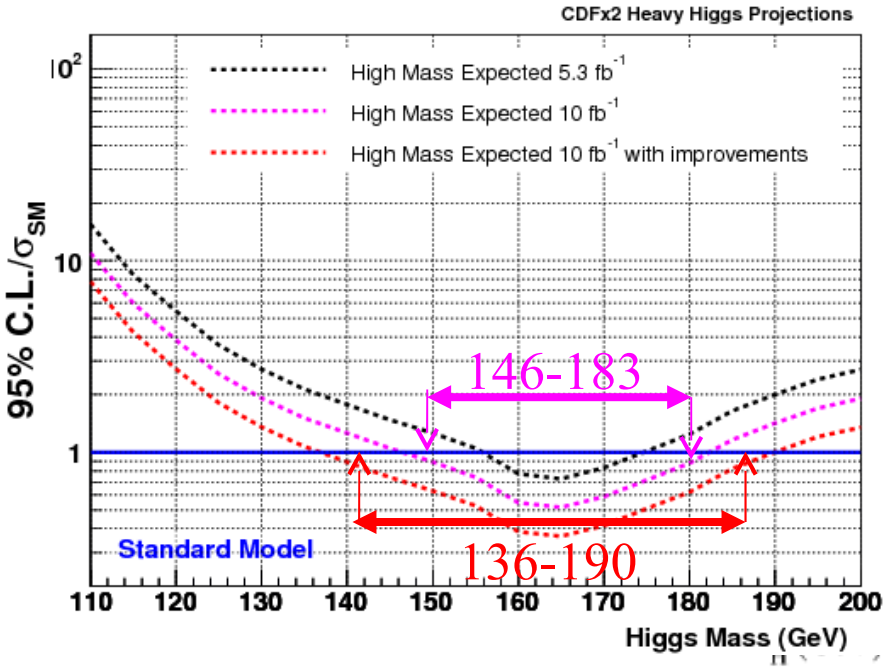
assume analysis will stay the same

known improvements will be implemented

"low mass" Higgs

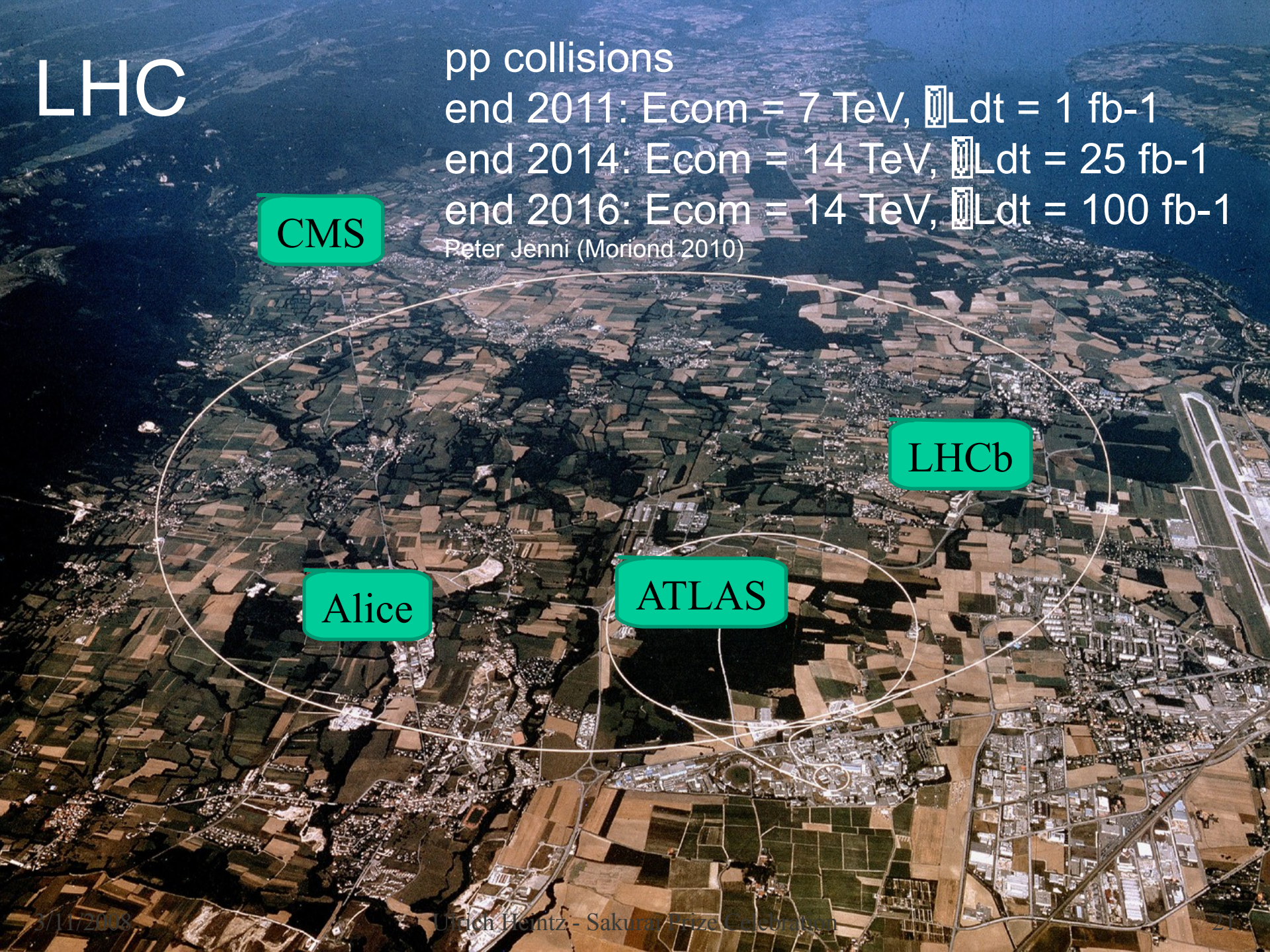
"high mass" Higgs



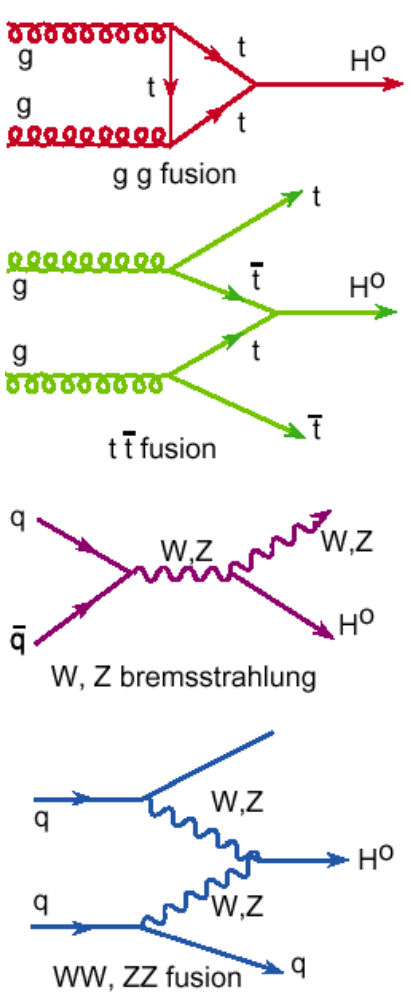


LHC

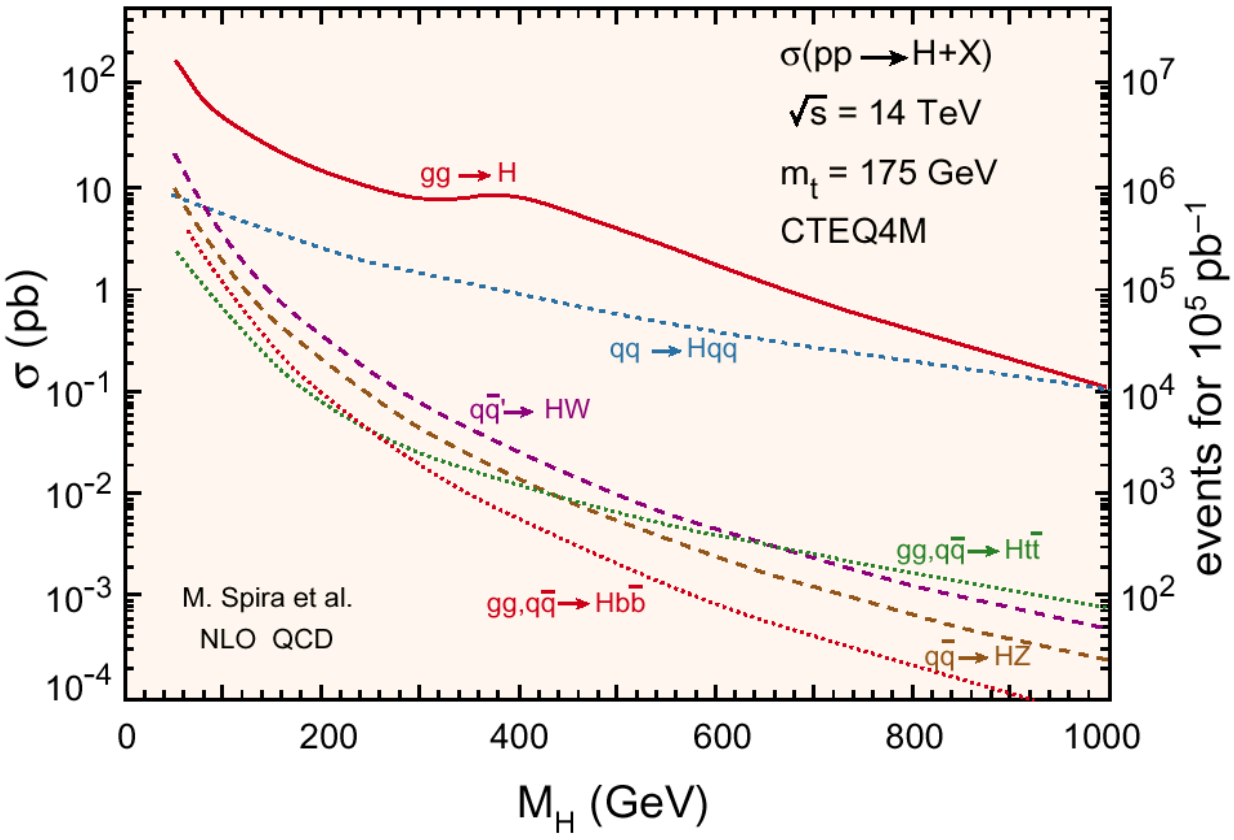
pp collisions
end 2011: Ecom = 7 TeV, ∫Ldt = 1 fb-1
end 2014: Ecom = 14 TeV, ∫Ldt = 25 fb-1
end 2016: Ecom = 14 TeV, ∫Ldt = 100 fb-1
Peter Jenni (Moriond 2010)



H production at LHC



Higgs production cross sections at LHC



CMS projections for H search

hard to see: H → bb

mH < 130 GeV

H → γγ

130 < mH < 190 GeV

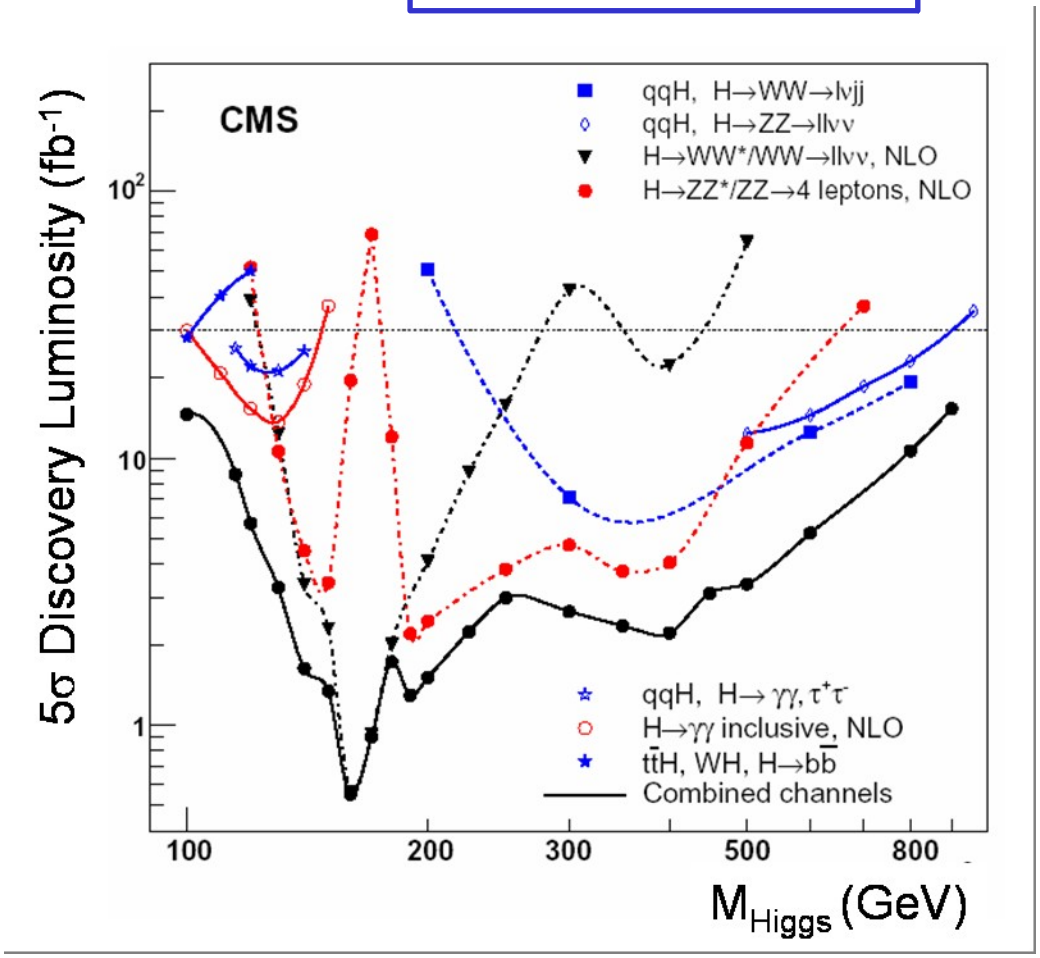
H → W+W- → ℓℓνν

190 < mH < 460 GeV

H → ZZ → ℓℓ ℓℓ

460 < mH < 800 GeV

H → W+W- → ℓνqq



designed to discover Higgs with 100 < mH < 800 GeV

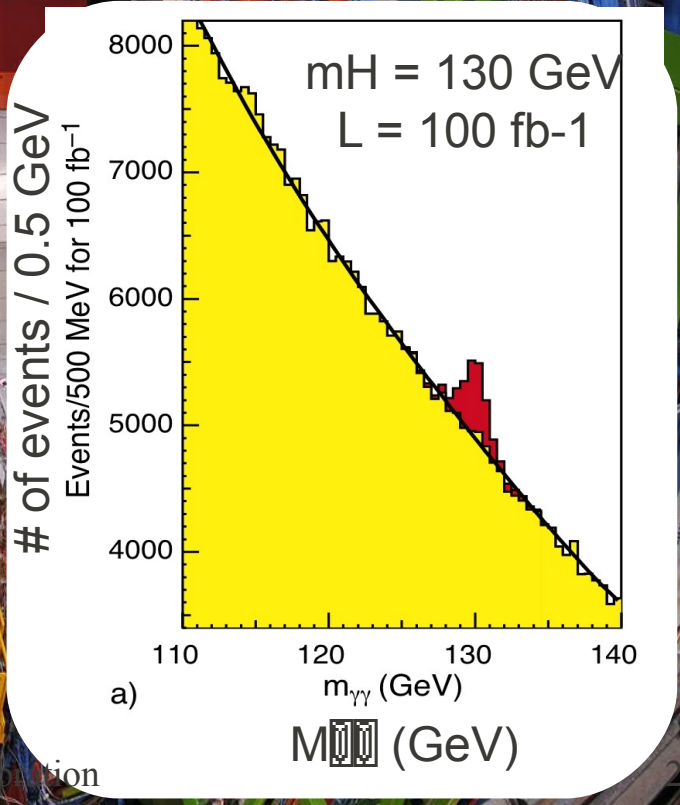
the CMS experiment

homogeneous electromagnetic calorimeter

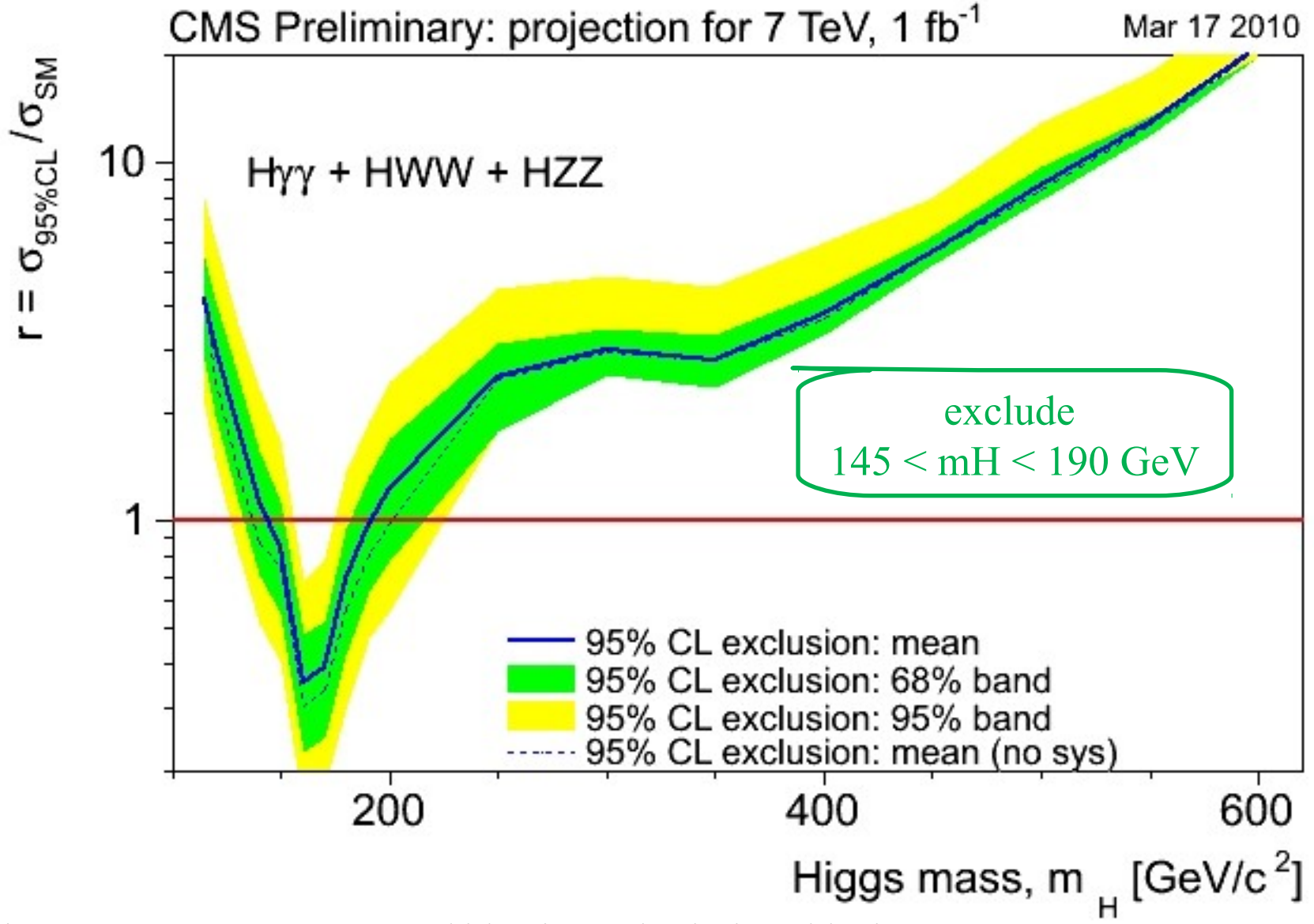
78,000 lead tungstate crystals

excellent photon energy resolution

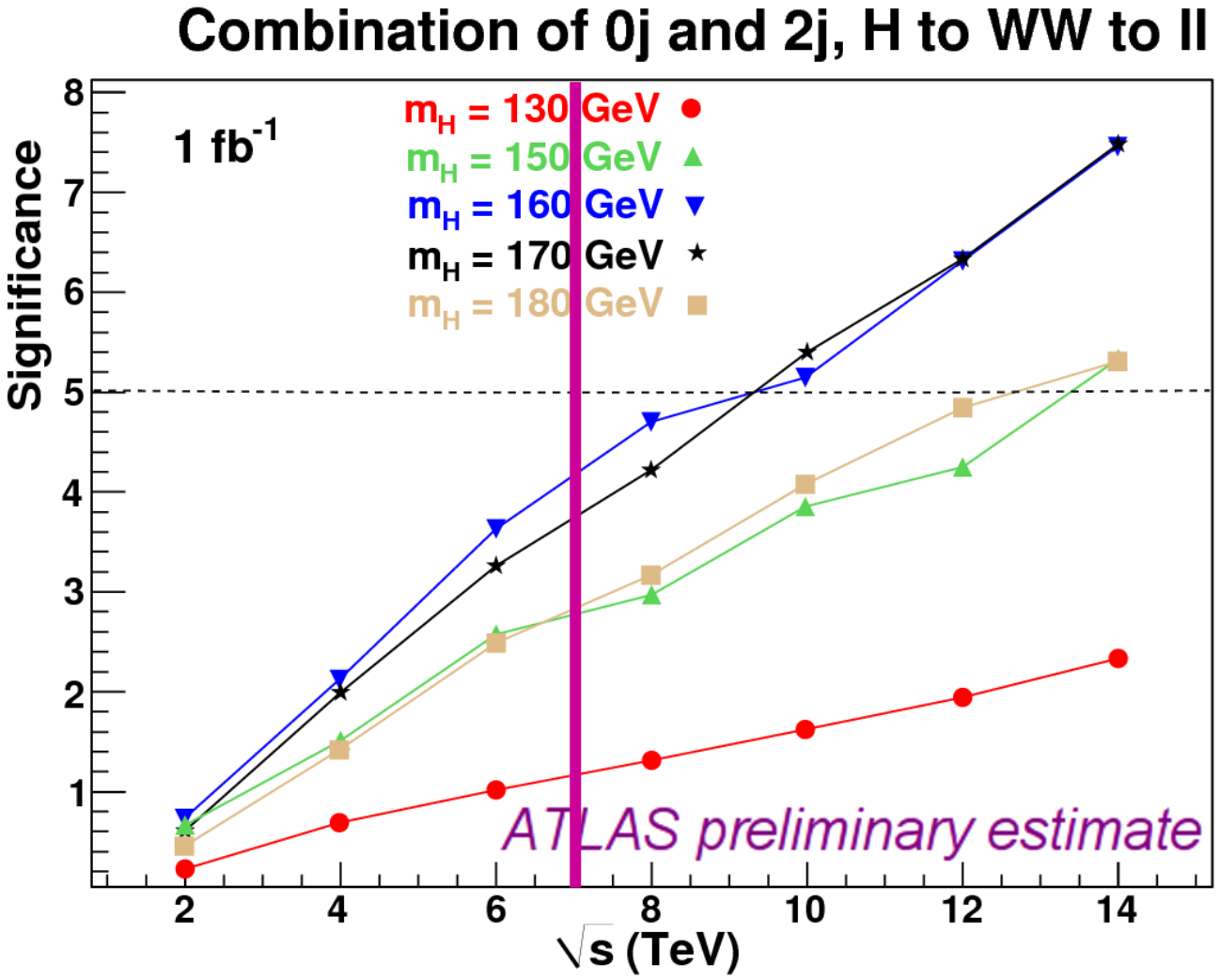
measure H→γγ

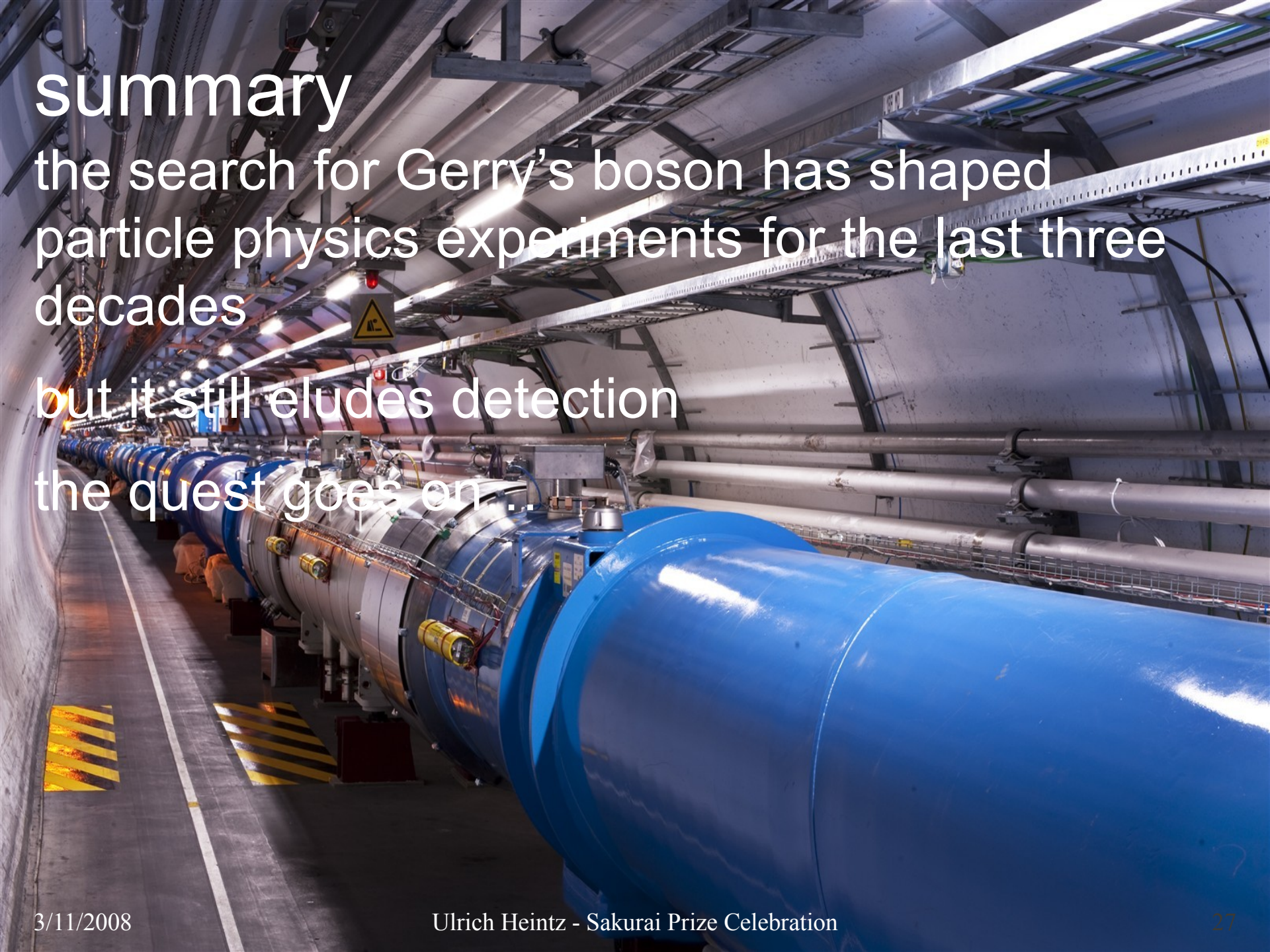


LHC projection for next 2 years



LHC projection for next 2 years





summary

the search for Gerry's boson has shaped particle physics experiments for the last three decades

but it still eludes detection

the quest goes on ..

Congratulations, Gerry!