LBNL and Electroweak symmetry breaking

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May 22, 2003

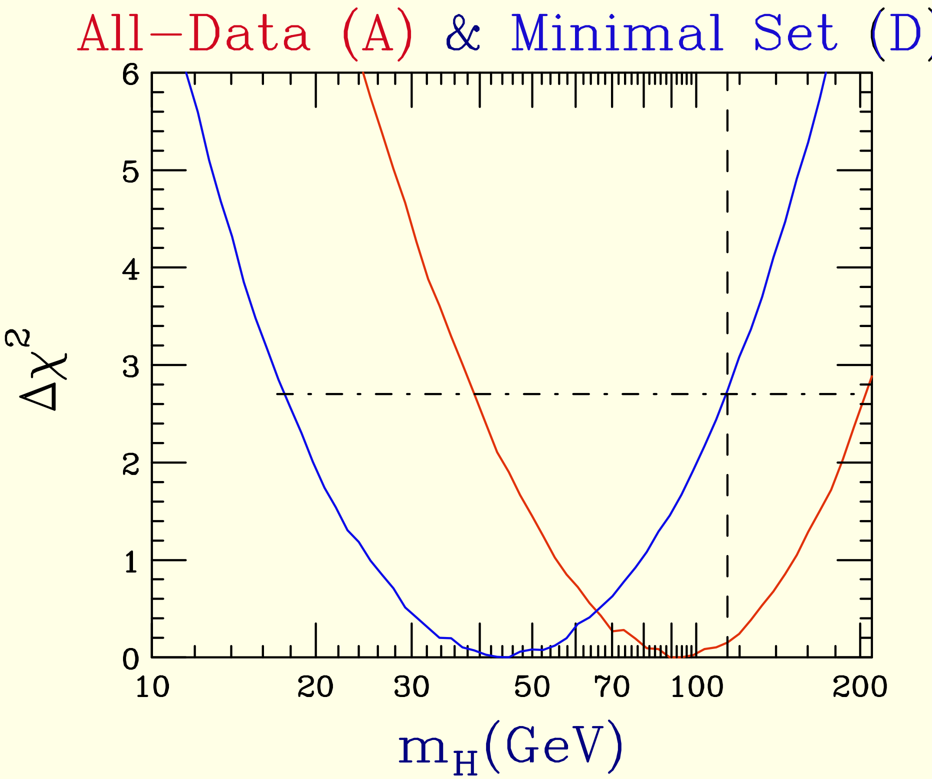
Outline

- Current status and problems
- LHC's role
- Linear collider's role
- LBL's role

The Status

Standard Model provides an excellent description of expermental phenomena.
Precision of better than 1% is achieved (LEP/SLC asymmetries, W/Z masses *etc*)
Need at least one extra particle to give mass to W/Z and all quarks/leptons — Higgs

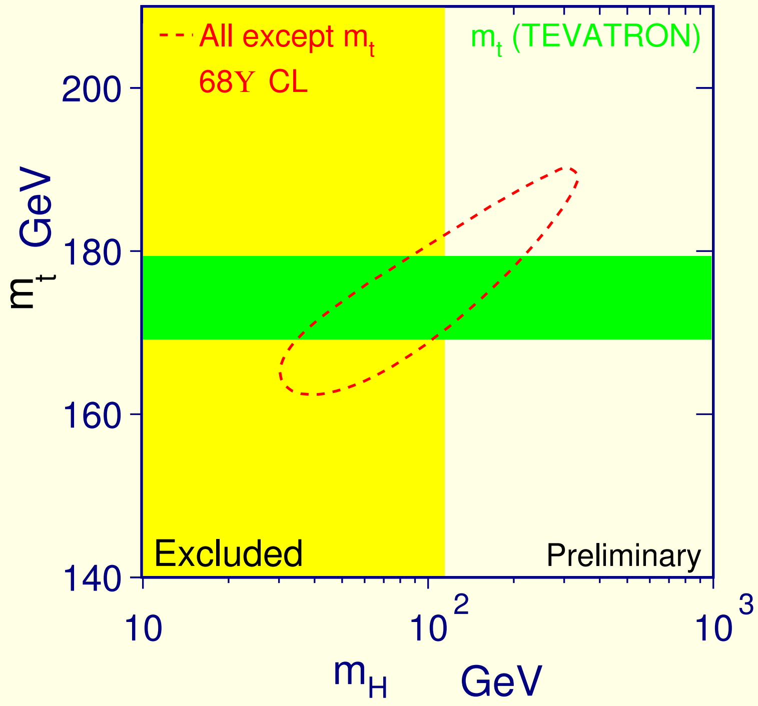
Plot shows $\Delta\chi^2$ as function of Higgs mass
All data has prob. of 2% at min
Excluding Hadronic asymmetry and neutrino scattering (Blue line) has prob. of 71% at min
Fit is now inconsistent with direct limit $M_H < 114$ GeV



Message – Things cannot be improved by ignoring measurements
Either unlucky or new physics
Chanowitz: LBNL-52452

Important not to overstate the inconsistency

Inference of Top mass from precision measurements agrees with direct observation



If the SM is right, then $M_H < 200 GeV$

If SM is not complete, Higgs structure could be more complicated with many new particles

The Challenges to Experiment and Theory

Theory

Why is Higgs light?

Generally test of SM get worse if new particles of masses below few TeV are added.

But radiative corrections to Higgs mass from top and W loops suggest a Higgs mass larger than the constraints allow.

Calculate with a cut off $\Lambda = 10 TeV$

top loop $\delta m_h^2 = \frac{3}{8\pi^2}\lambda_t^2\Lambda^2 \sim (2TeV)^2$

W/Z loops $\delta m_h^2 \sim \alpha_w \Lambda^2 \sim -(750GeV)^2$

Theorists like to solve this by adding other new particles to cancel these effects – simplest example is SUSY where stop cancels top etc

This predicts other new particles

Open question is "What breaks ElectroWeak symmetry?"

There must be at least one particle yet to be discovered.

LHC's Task

Find the particle(s) responsible for mass generation.

Could be Higgs, many Higgs's, SUSY, Extra dimensions

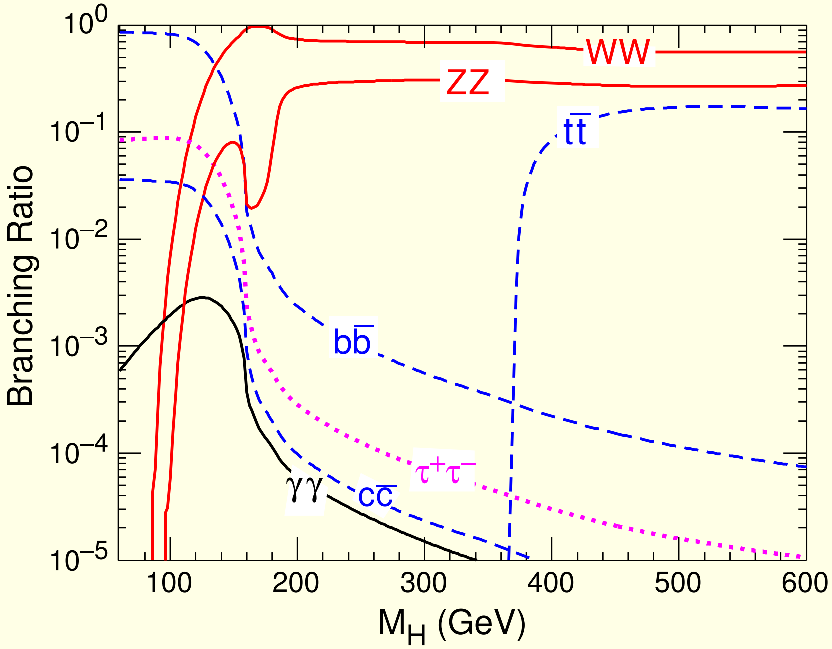
Power of LHC is its enormous mass reach relative to current facilties.

Even low luminosity will open a new window.

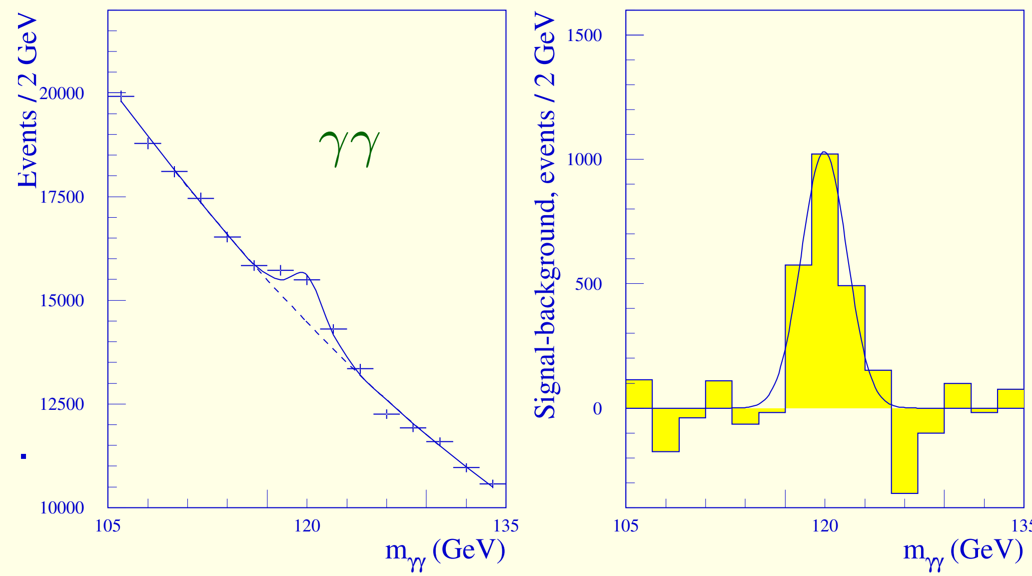
$10pb^{-1}$ (1 day at 1/100 of design luminosity) gives 8000 $t\bar{t}$ and 100 QCD jets beyond the kinematic limit of the Tevatron

If SUSY is correct, it could be found with $100pb^{-1}$

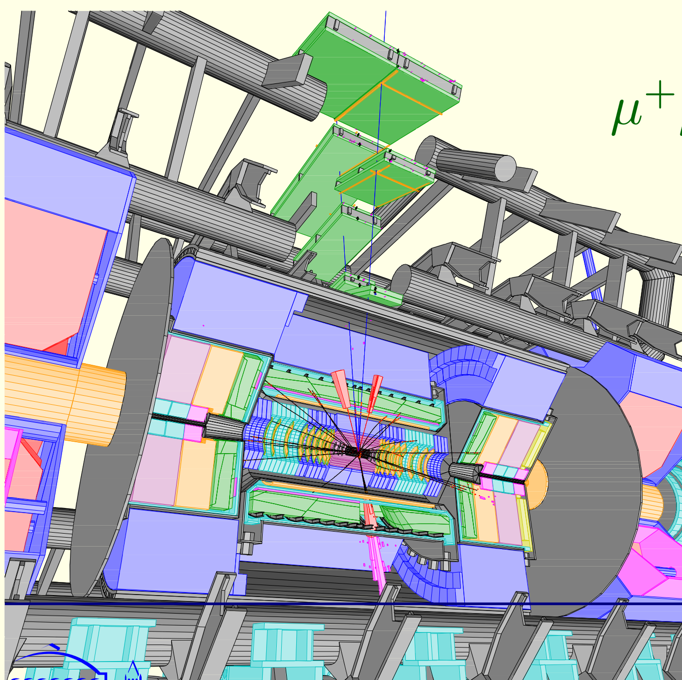
Let's start with quick reminder of a few Higgs signalks



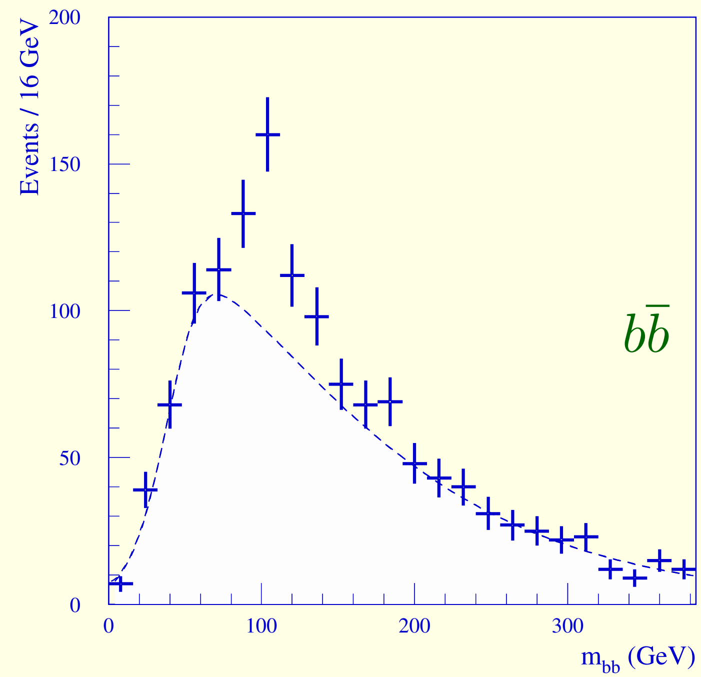
Branching Ratio
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
100
200
300
400
500
600
M_H (GeV)
WW
ZZ
$t\bar{t}$
$b\bar{b}$
$\tau^+\tau^-$
$c\bar{c}$
$\gamma\gamma$



Events / 2 GeV
20000
17500
15000
12500
10000
105
120
135
$m_{\gamma\gamma}$ (GeV)
$\gamma\gamma$
Signal-background, events / 2 GeV
1500
1000
500
0
105
120
135
$m_{\gamma\gamma}$ (GeV)



$\mu^+\mu^-e^+e^-$



Events / 16 GeV
200
150
100
50
0
0
100
200
300
m_{bb} (GeV)
$b\bar{b}$

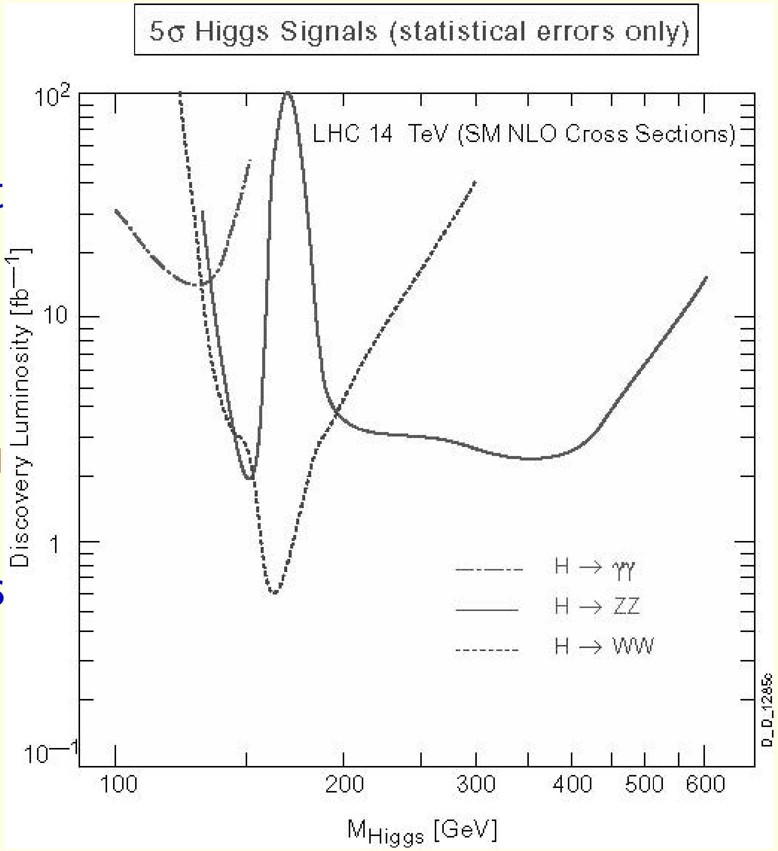
Higgs is not a "typical" LHC discovery as it demanding of luminosity

Plot shows luminosity need to discover Higgs

Easiest channel depends on mass

The envelope of these curves shows how long you have to wait!

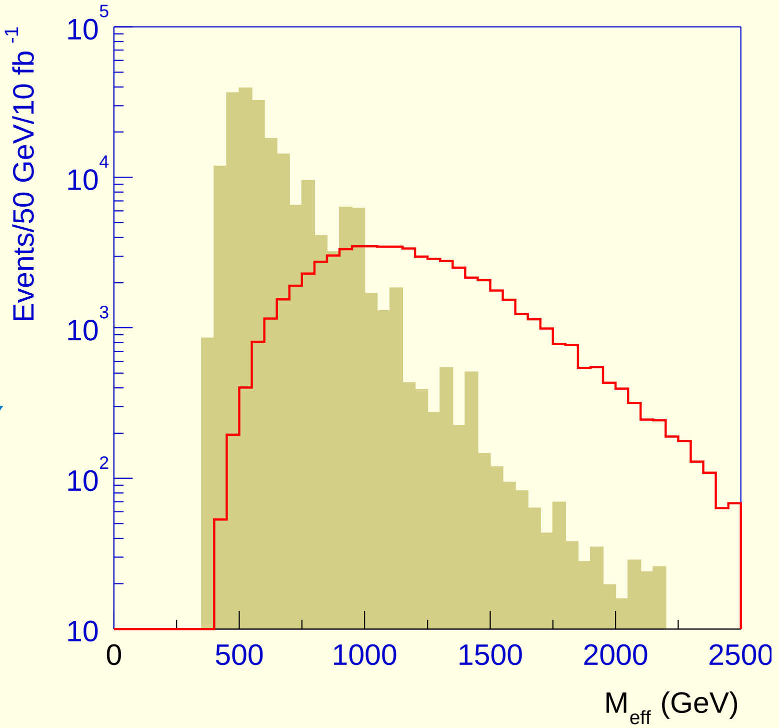
In worst case (just above the LEP limit) $10 fb^{-1}$ is needed per experiment



New particle exammple – SUSY

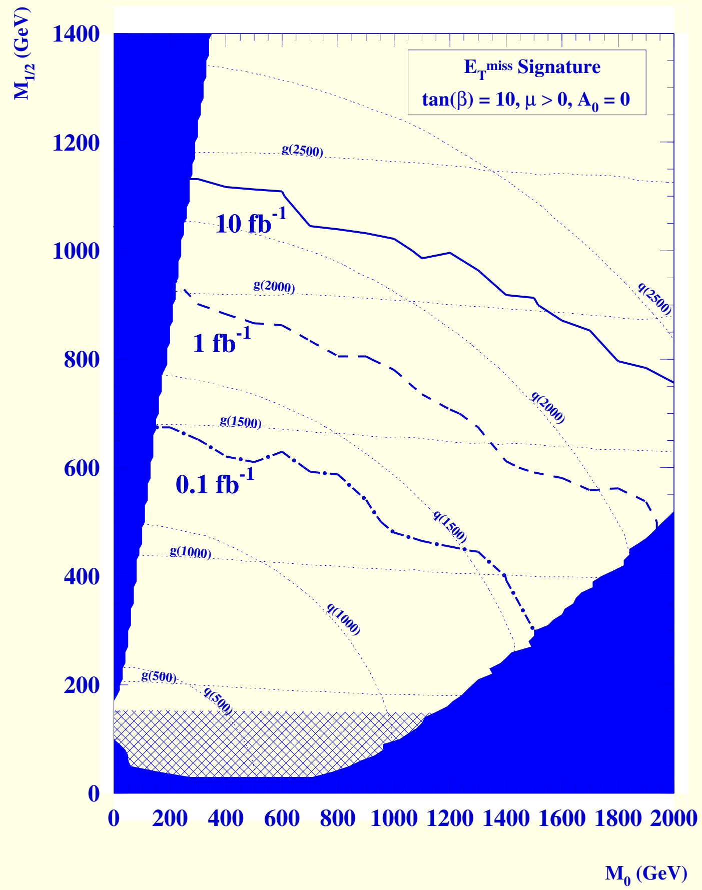
Produces events with jets and missing transverse energy

Select events with at least 4 jets and Missing E_T
A simple variable
$M_{\text{eff}} = P_{t,1} + P_{t,2} + P_{t,3} + P_{t,4} + \not{E}_T$
At high M_{eff} non-SM signal rises above background
Note scale – huge event rate
Peak in M_{eff} distribution correlates well with SUSY mass scale
$M_{\text{SUSY}} = \min(M_{\tilde{u}}, M_{\tilde{g}})$
This example has susy masses around 700 GeV



This signal is characteristic of any new physics at a large mass

How fast can SUSY be found?

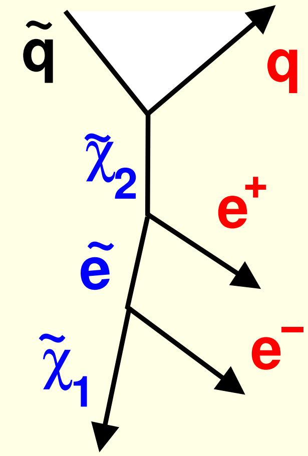


Plot shows reach in SUSY model space
Solid region is not allowed
Hatched region is already ruled out by LEP
Contours label squark and gluino masses and luminosity
Example – $0.1 fb^{-1}$ discovers gluino of mass 1.4 Tev
This is 1 year at 1/1000 of design luminosity!

Need to be ready to do physics at day one

An example of a recent full simulation study

Decay $\tilde{q}_L \to q\widetilde{\chi}_2^0 \to q\widetilde{\ell}\ell \to q\ell\ell\widetilde{\chi}_1^0$
Produces a pair of e^+e^- or $\mu^+\mu^-$ with a restricted invarient mass.



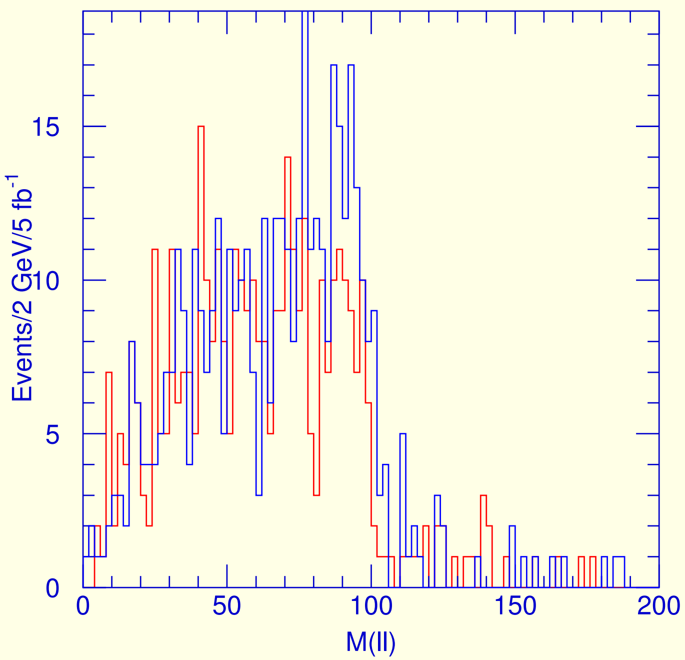
100K events simulated and reconstructed with new software (LBL lead role)

Corresponds to $5fb^{-1}$

Needed 50K CPU hrs, approx half of this was done on PDSF

First "physics test" of new reconstruction, results shown to ATLAS last week

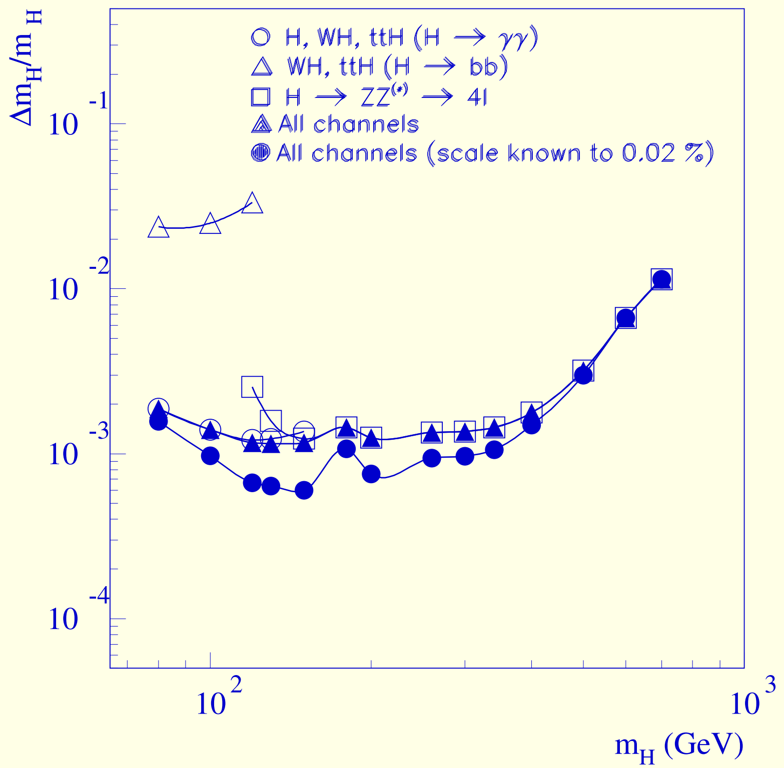
Plot shows invarient mass distribution of $\mu^+\mu^-$ (blue) and e^+e^- (red)
Note this example is $5 fb^{-1}$
Standard model background not shown, its mainly from $t\bar{t}$ and is very small



Leads to measurements of some masses to 1 GeV precision

More complicated topologies can be reconstructed starting here and adding jets.

Linear Collider's Task



LHC can measure the mass of Higgs precisely
Plot shows mass error for various masses

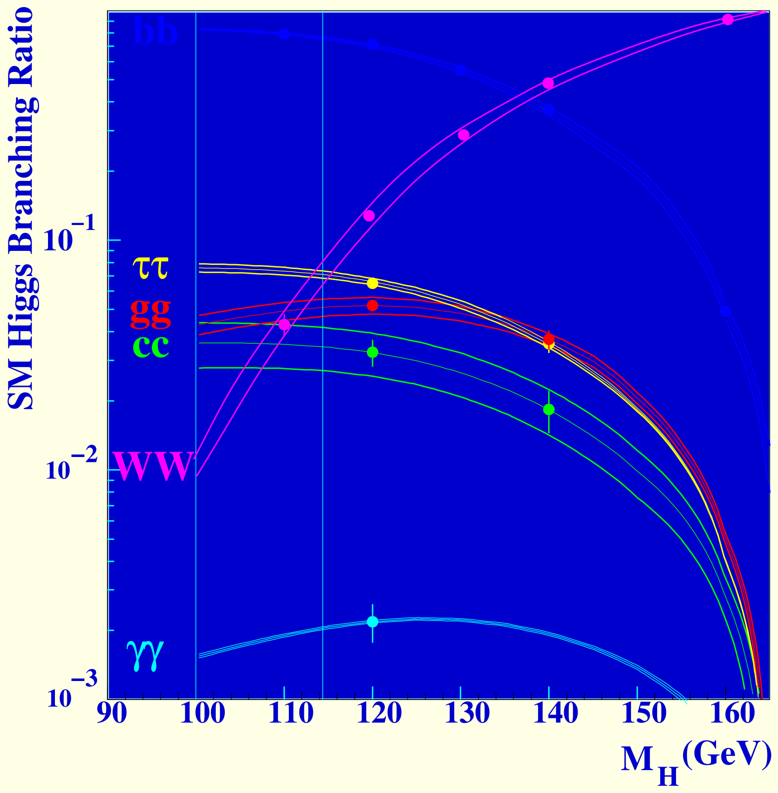
LHC's measurements of Higgs decay properties depend on mass.
In low mass (favored) region precision is limited by
Theoretical uncertainties in cross-sections
Absolute luminosity measurement
Statistics and Backgrounds
Not all channels will be visible.

Berkeley Lab

Precision studies will need another facility

Precision measurements of decay modes will require facility that can produce the Higgs in a controlled enviromment. Such a faciltity will be to the Higgs what LEP was for Z

PLot shows the Higgs branching ratios as a function of mass errors from an LC simulation (Battaglia)



LBNL participation in important EW milestones

- 1984 Hinchliffe *et al* "SuperCollider Physics"
- 1986 (check) SSC Central design group
- 1989-1993 SDC
- 1990 Precise W mass from Tevatron (CDF)
- 1998 Precise Tevatron top mass (D0 and CDF)
- 1988 Measurement of Z mass (mark II at SLC and CDF)
- 1994 Join ATLAS
- 1996 Peskin and Murayama Linear collider "Ann.Rev.Nucl.Part.Sci"
- 2001 "A CONSTRAINED STANDARD MODEL FROM A COMPACT EXTRA DIMENSION" Hall, Nomura
- 2000 Implications of precision EW data (Chanowitz)
- 200x Susy discovered by atlas
- 201x Linear collider measures all Higgs branching ratios