Rapidity

rapidity → $y \equiv \frac{1}{2} \ln \frac{E + p_z}{E - p_z} = \frac{1}{2} \ln \frac{\sqrt{M_{ee}^2 + p_z^2} + p_z}{\sqrt{M_{ee}^2 + p_z^2} - p_z}$

$$x_1 = \frac{E + p_z}{\sqrt{s}} \qquad x_2 = \frac{E - p_z}{\sqrt{s}}$$

$$y = \frac{1}{2} \ln \frac{x_1}{x_2}$$

$$\frac{x_1}{x_2} = e^{2y}$$

$$x_1 x_2 = \frac{M^2}{s}$$

$$x_1^2 e^{-2y} = \frac{M^2}{s}$$

$$\boxed{x_1 = \frac{M}{\sqrt{s}} e^{y} \qquad x_2 = \frac{M}{\sqrt{s}} e^{-y}}$$

could transform to

$\frac{d^2\sigma}{dM\,dy}$ actually easier.

Decays

Problem: $Z^0 \to l^+ l^- \simeq 3.3\%$ per charged lepton.

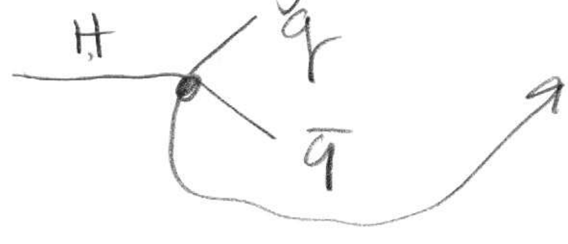
$W^{\pm} \to l^{\pm} \overset{(-)}{\nu}_e \simeq 10\%$

At LHC, TeV, $Z^0 \to q\bar{q} \to$ jets

$W \to q_1 \bar{q}_2 \to$ jets

hard to separate from background.

Higgs Boson

1. Spin - 0.
2. mass a "free parameter"
3. **Essential** for completing standard model.
   Keeps "wrong helicity" branching ratios from ∞
4. 

   $\propto m_q$ (!)

Makes Mass

H → condensed field

Key point:

$\Gamma(H^0 \to q\bar{q}) \propto m_q^2$

$\Rightarrow$ Heavy Quarks favored

$\Rightarrow$ Z^0Z^0, W^+W^- also favored (if m_H large enough

(5) LEP:

$115\ \text{GeV} \leq M_H \leq 165\ \text{GeV}$

not above $H^0 \to Z^0Z^0$

barely $H^0 \to W^+W^-$

no $H^0 \to t\bar{t}$

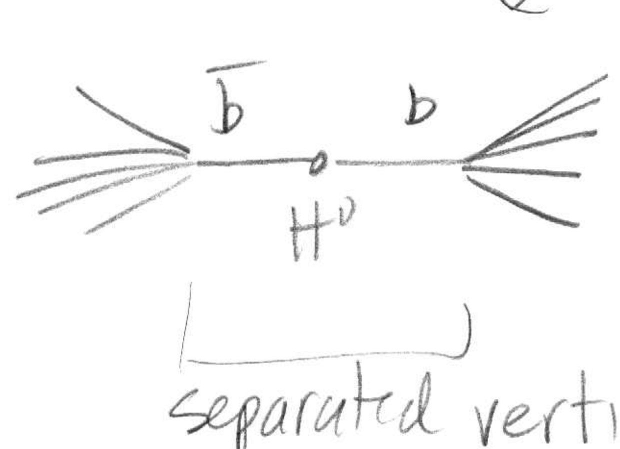
What does it do?

mostly $H^0 \to b\bar{b}$ (plot).

$\Rightarrow$ really hard

$\Rightarrow$ hope

1.5 ps life



"Golden Mode" $\Rightarrow$ $H^0 \to Z^0 Z^0$

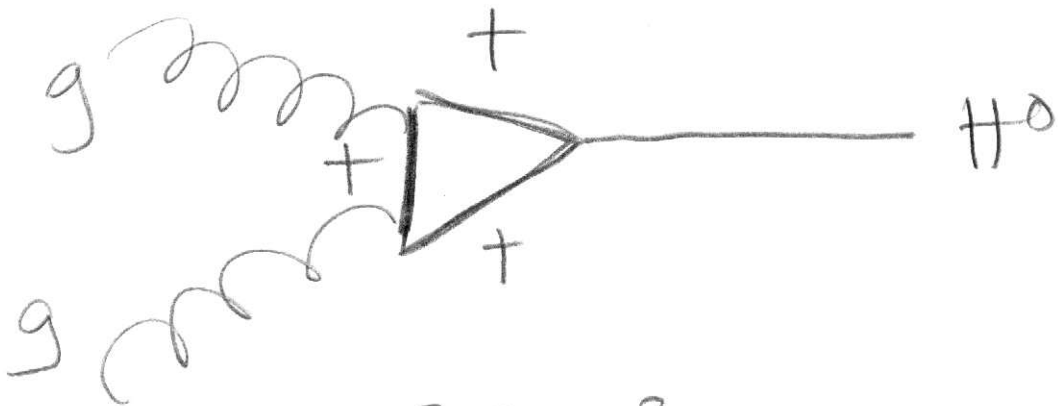
$\to$ 4ℓ

2ℓ2ν

"Discovery" plot

Production:

Mainly



$$\sigma = \frac{\alpha_s^2 G_F M_H^2}{\pi \sqrt{2}\, 2^5 3^2}\, \delta(\hat{s} - M_H^2)$$

(narrow width)

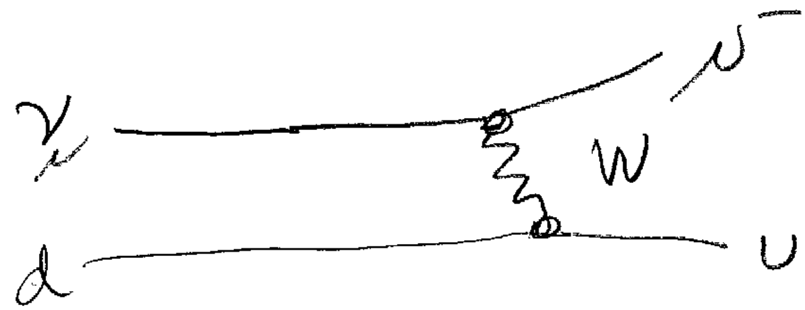
⇒ you calculate

⇒ plot

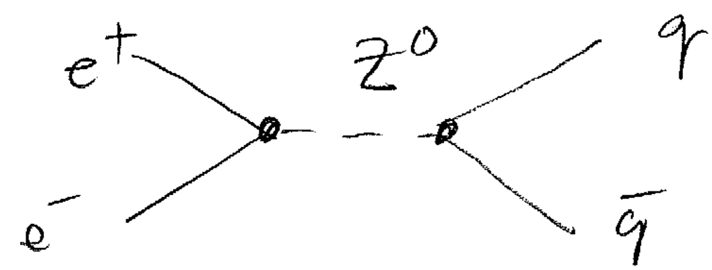
⇒ discovery plot.

Sensitivity to Higgs Mass due to "Higher Order" effects.

① Running with Q^2



$Q^2 \sim$ few GeV^2

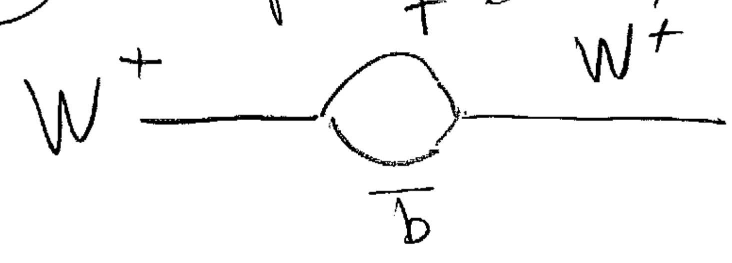


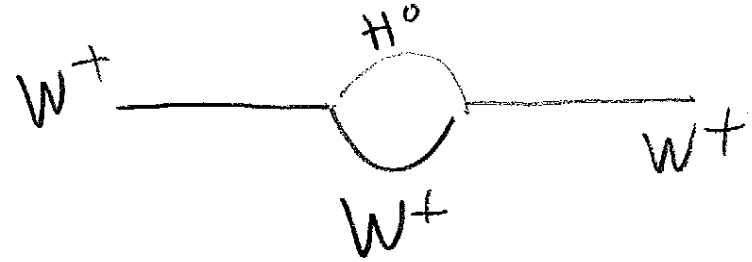
$Q^2 \sim (100)^2 GeV^2$

Vertex couplings are <u>not</u> constant, vary with Q^2 or length scale.

② Loops

t ← very heavy.

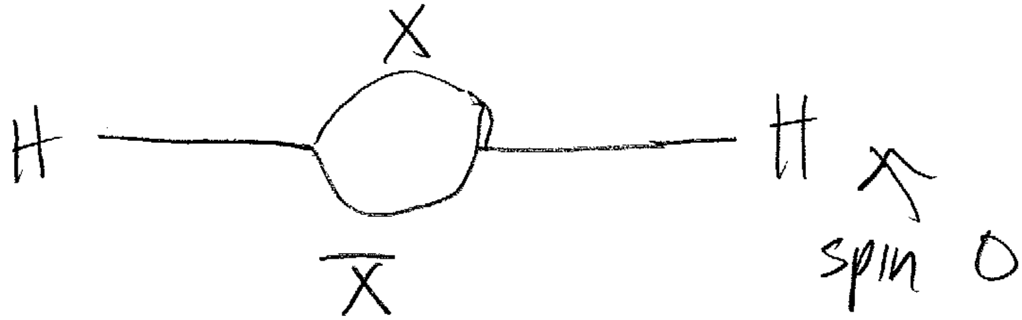




<u>2 plots</u>

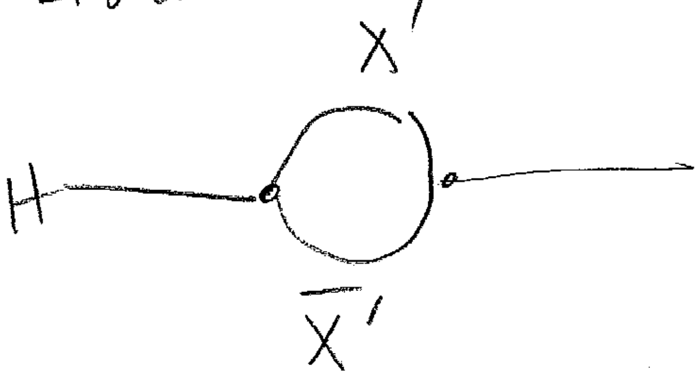
General View Point

Higgs is "light", $\lesssim 200\ GeV/c^2$



X → unknown.. but problem is, would make the Higgs ∞ in mass (effectively).

Idea....



with − sign!

X → fermion

X′ → boson

"Supersymmetry"

Table

Key idea:

- "Gauge Couplings" of superpartners...

$\underbrace{\gamma, Z^0/W^+, g}$

same as original partners

e^- $\tilde{e}^-$

spin $\frac{1}{2}$ spin 0, "scalar" electron

Identical: em charge
Weak charge
color charge

Woops: e_R^- + e_L^- diff. Z^0

Two scalars! → $\tilde{e}_L^-$ $\tilde{e}_R^-$

- Superpartners have a new quantum # . . .

"R" Parity ... conserved. (maintains stable proton).

see table

Meaning: very important: superpartners must be pair produced . . .

- "Mixing"

Spin-$\frac{1}{2}$ partners of:

γ, Z^0, H^0 ($\Leftarrow$ 2!).

$\tilde{\gamma}$, $\tilde{Z}^0$, $\tilde{H}^0$, $\tilde{H}^{0\prime}$

are not eigenstates!

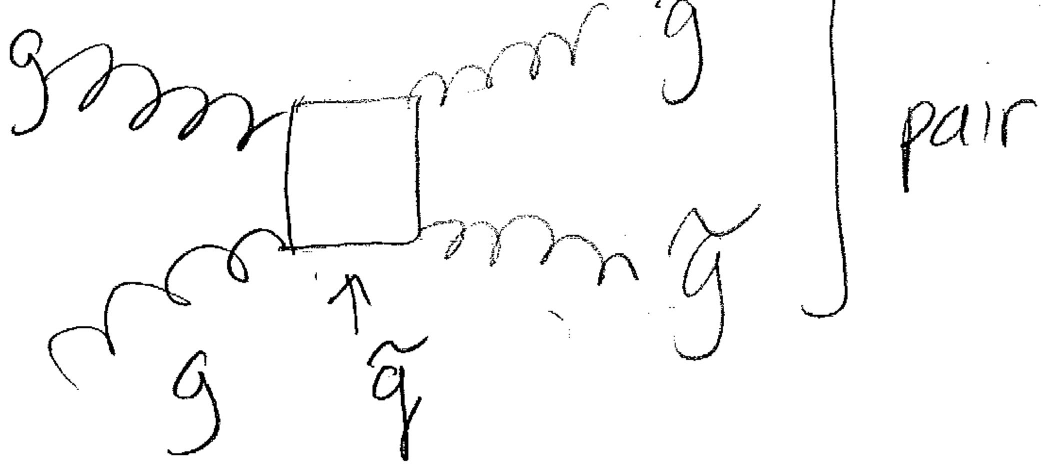
Lightest ... χ^0 ... cannot decay

Spin $\frac{1}{2}$ partners of W^+/H

$\widetilde{W}^+, \widetilde{H}^+$ ... can mix.

χ_1^+, χ_2^+

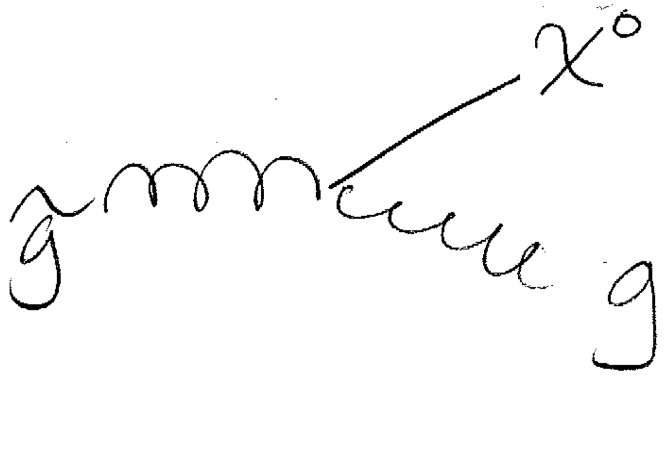
- <u>Decays</u>: $gg \to \tilde{g}\tilde{g}$



$\tilde{g}$: stuck with R-parity

usually $m_{\tilde{g}} > m_{\chi^0}$

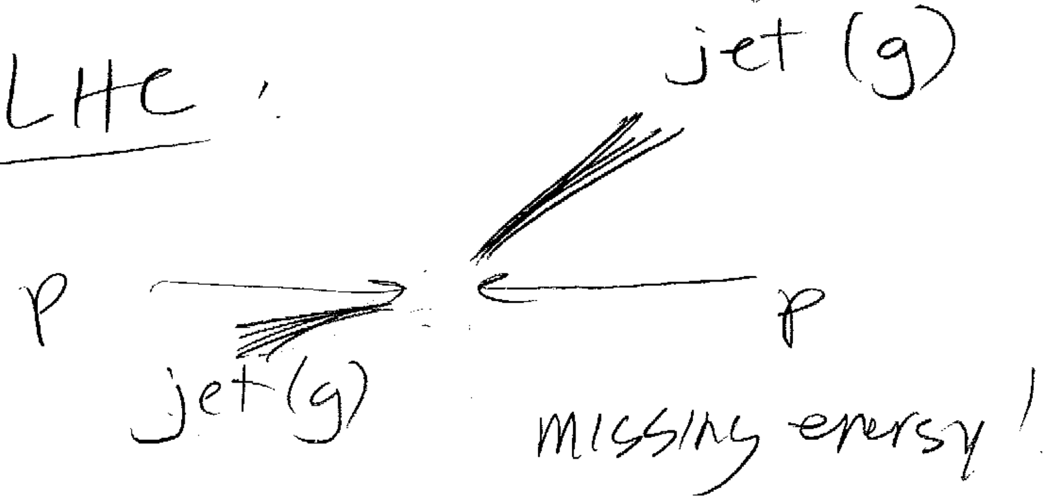
Maybe:



$\chi^0 \rightarrow$ escapes undetected

$\rightarrow$ missing energy!

<u>LHC</u>:



<u>Usually</u>: all SUSY pair production causes missing energy.

- Masses of partners/s-p <u>can</u> be different.