Recent Studies on Top Physics at JLC

Measurments of Top Yukawa Coupling

Keisuke FUJII : KEK

- Introduction
- Threshold Region
- Higher Energy Region
- Summary

Introduction

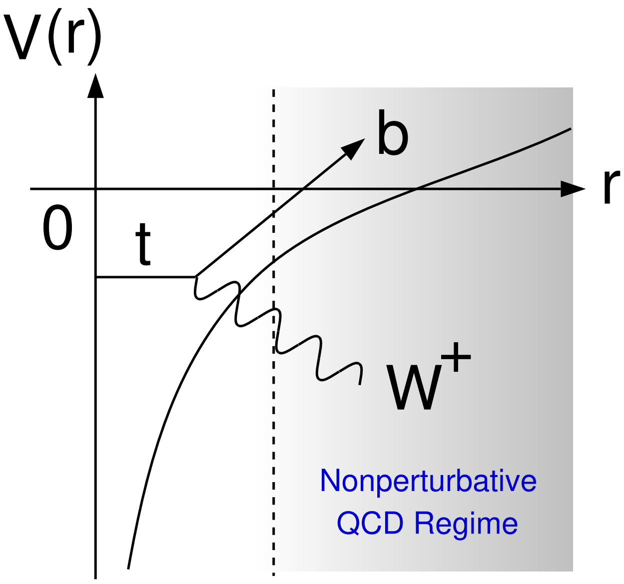
Fact

$$M_W < m_t \cong 175 \text{ GeV}$$

Implications

- We need a 0.5 TeV LC as a top factory.
- There is a chance to see top Yukawa interaction.
- Γ_t is LARGE ($\Gamma(t \to bW_L)$: LARGE)

$$\Gamma_t \cong 1.4 \text{ GeV for } m_t \cong 175 \text{ GeV}$$



Top decays before entering non-perturbative QCD regime!

Γ_t = Infrared Cutoff

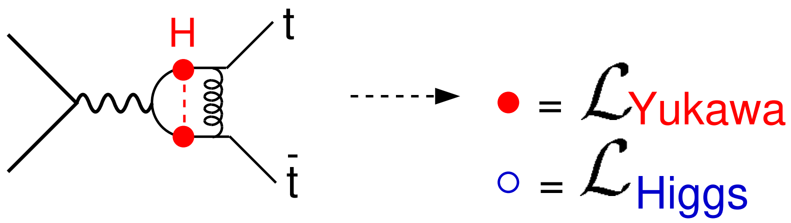
Reliable cross section calculation based on PERTURBATIVE QCD

Fadin-Khoze

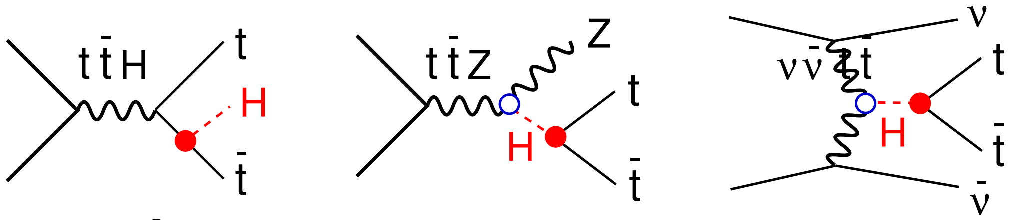
- - - -► Clean α_s measurements
- - - -► Other tiny effects: extractable

Measurements of Top Yukawa Coupling

$\sqrt{s}$ = 300~500 GeV



$\sqrt{s} \gtrsim$ 500 GeV



$m_H < 2\, m_t$ $\quad$ $m_H < 2\, m_t$

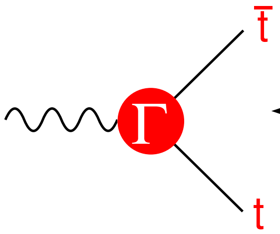
Threshold Region

Quick Review

Key Point

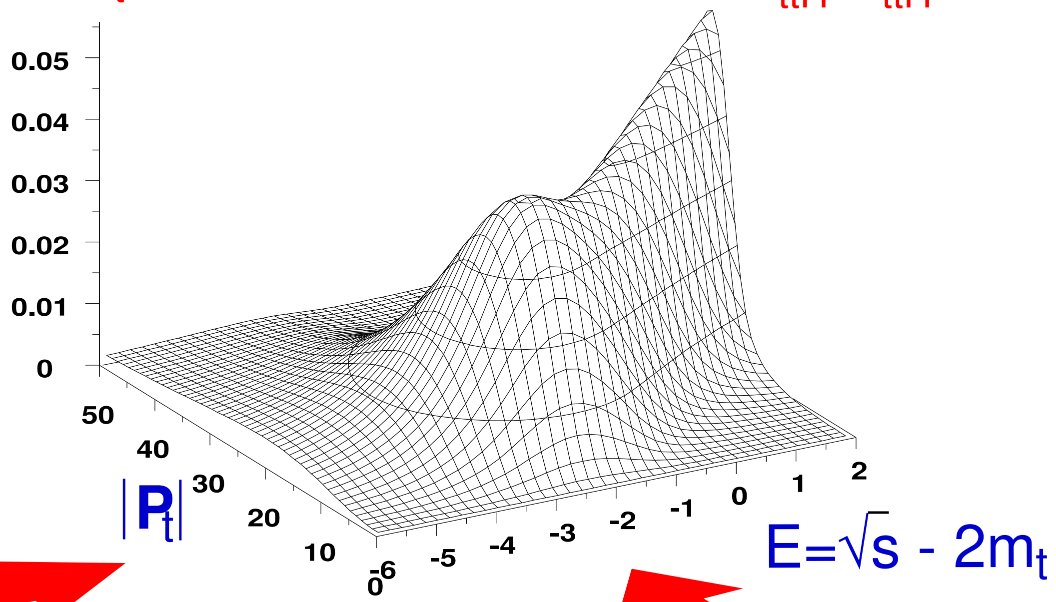
Large Γ_t = Infrared Cutoff $\dashrightarrow$ Reliable theoretical predictions

Essentially all the physics in G!



$\longleftrightarrow$ $G\,(\,E;\, m_t,\ \Gamma_t, \alpha_s\,, m_H\,,\ \beta_H\,)$

$\beta_H \equiv g_{ttH}/g_{ttH}(SM)$



Momentum Dist.

$$\frac{d\sigma_{t\bar{t}}}{d|\mathbf{p}|} \propto \left|\langle\, \mathbf{p}\,|\,G\,|\,\mathbf{x}=\mathbf{0}\,\rangle\right|^2$$

$$\approx \left|\sum_n \frac{\phi_n(\mathbf{p})\ \Psi_n^*(\mathbf{0})}{E - E_n + i\Gamma_n\ /\ 2}\right|^2$$

$100\ \text{fb}^{-1}$ if E_{1S}: known

$\Delta\alpha_s \cong \mathbf{0.002}$

$\Delta\Gamma_t/\Gamma_t \cong \mathbf{0.04}$

Threshold Scan

$$\sigma_{t\bar{t}} \propto \text{Im}\,\langle\,\mathbf{x}=\mathbf{0}\,|\,G\,|\,\mathbf{x}=\mathbf{0}\,\rangle$$

$$\approx \text{Im}\sum_n \frac{|\Psi_n(\mathbf{0})|^2}{E - E_n + i\Gamma_n\ /\ 2}$$

$10\ \text{fb}^{-1}$ m_t=150 GeV

$\Delta m_t \cong \mathbf{0.2\ GeV}$ $\Delta\Gamma_t/\Gamma_t \cong \mathbf{0.2}$

$\Delta\alpha_s \cong \mathbf{0.005}$

Higgs Exchange = Short Range Force

$$V_{Higgs}(r) = -\frac{\sqrt{2}\,G_F}{4\pi}\,(\beta_H m_t)^2\,\frac{e^{-m_H r}}{r}$$

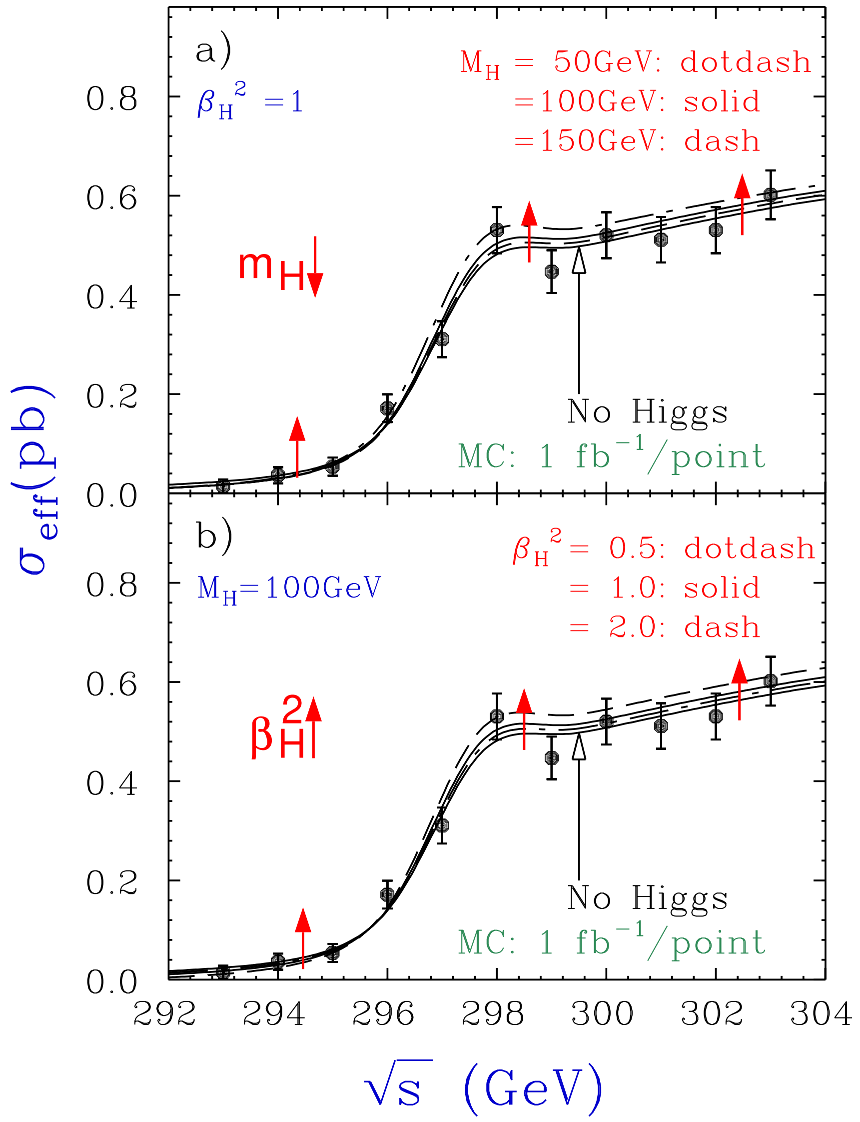
only changes the overall normalization

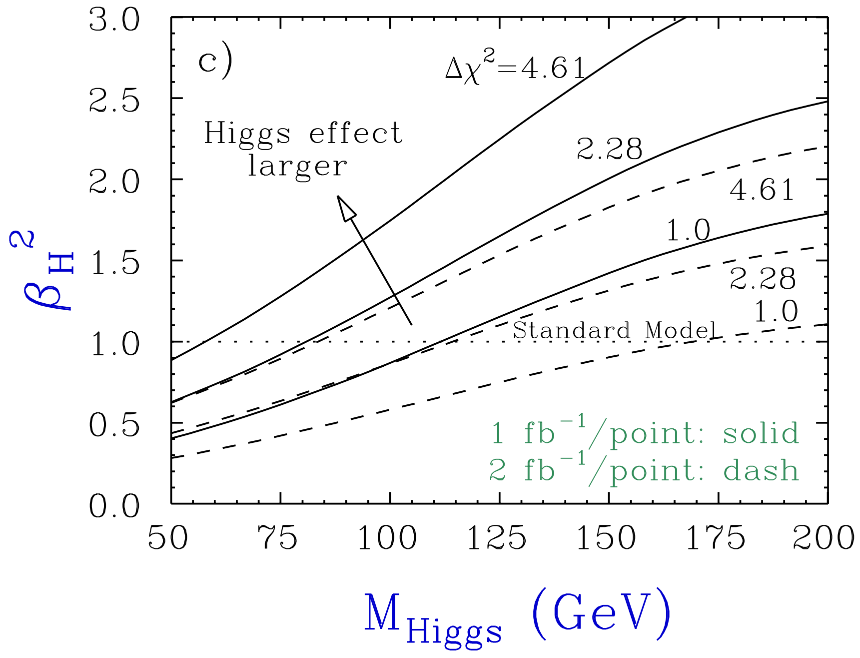
Insensitive to Higgs Exchange!

Sensitive to Higgs Exchange!

m_H-β_H^2 Fit

$\beta_H \equiv g_{ttH}/g_{ttH}(SM)$





Input MC data

m_{top}=150GeV

α_s = 0.12

$|V_{tb}|^2$=1

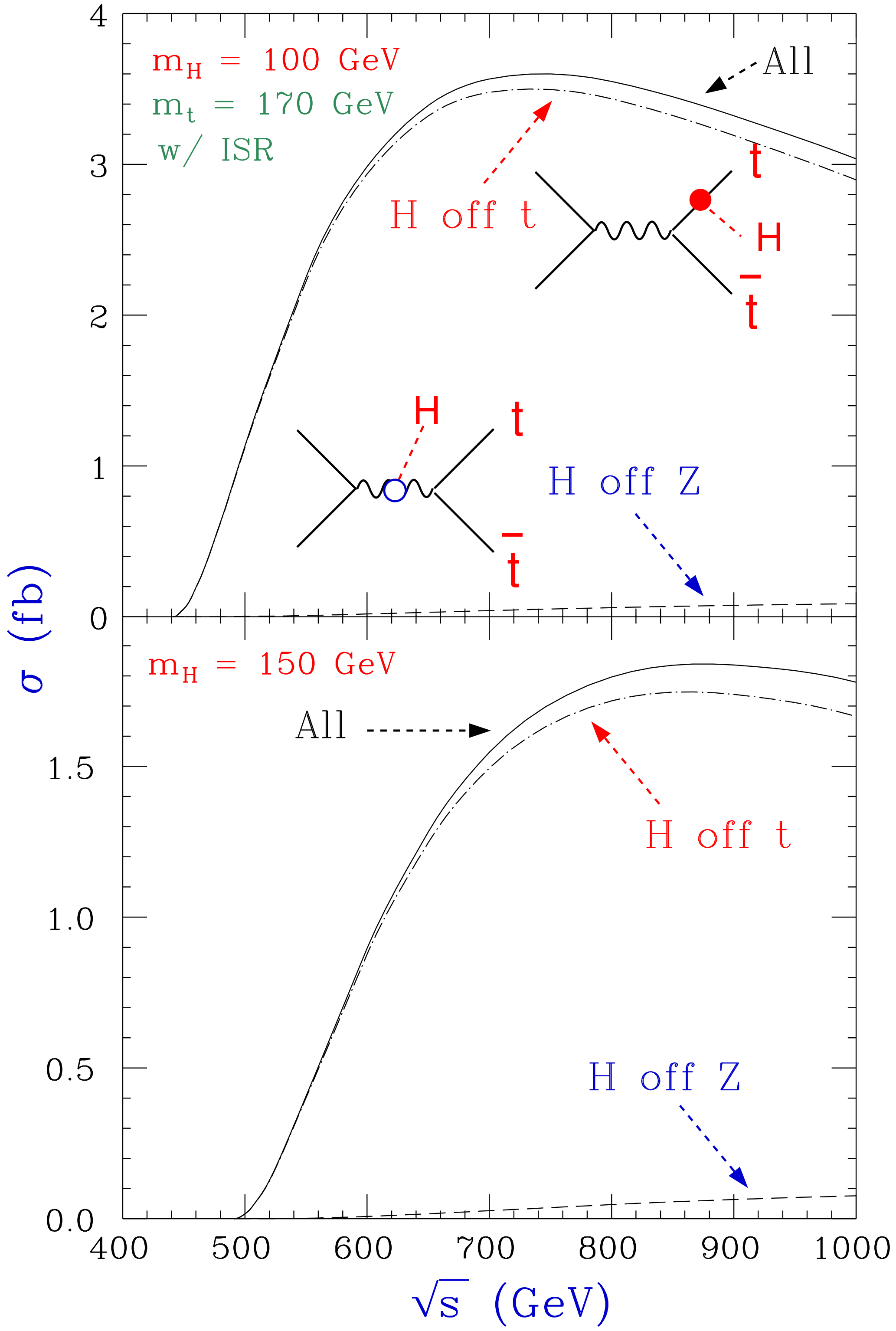
No Higgs

$$V_{Higgs}(r) = -\frac{\sqrt{2}\,G_F}{4\pi}(\beta_H m_t)^2 \frac{e^{-m_H r}}{r}$$

$\Delta\beta_H \cong 0.29$ (m_H= 100GeV:SM)

Higher Energy Region

$e^+e^- \rightarrow t\bar{t}H$ ---------- Direct Measurment of Top Yukawa Coupling

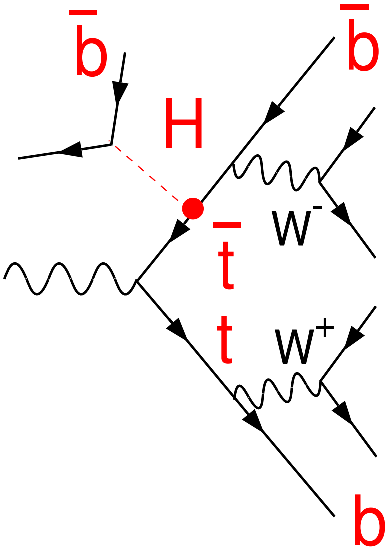


Higgs-strahlung diagrams dominate !

Events $\propto \beta_H^2$

Event Selection

Signal of $t\bar{t}H$ Production



2 W's and 4 b's

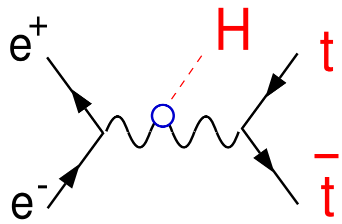
$\rightarrow q\bar{q}', l\nu$

	BR(SM)
8J	38%
L+6J	37%

Background

$BG = e^+e^- \rightarrow t\bar{t}Z$

+ Non-H-off-t Diagram + $e^+e^- \rightarrow t\bar{t}$ with gluon emission



Irreducible

Big but Reducible

Basic Cuts

Event Shape

#jets = 8 or 6

Thrust < 0.8

Mass Cuts

$m_{2J} \cong m_W / m_H$

$m_{3J} \cong m_t$

E,P Balance (8J)

$P_T < 50\text{GeV}$

$\Delta E_{vis} < 200\text{GeV}$

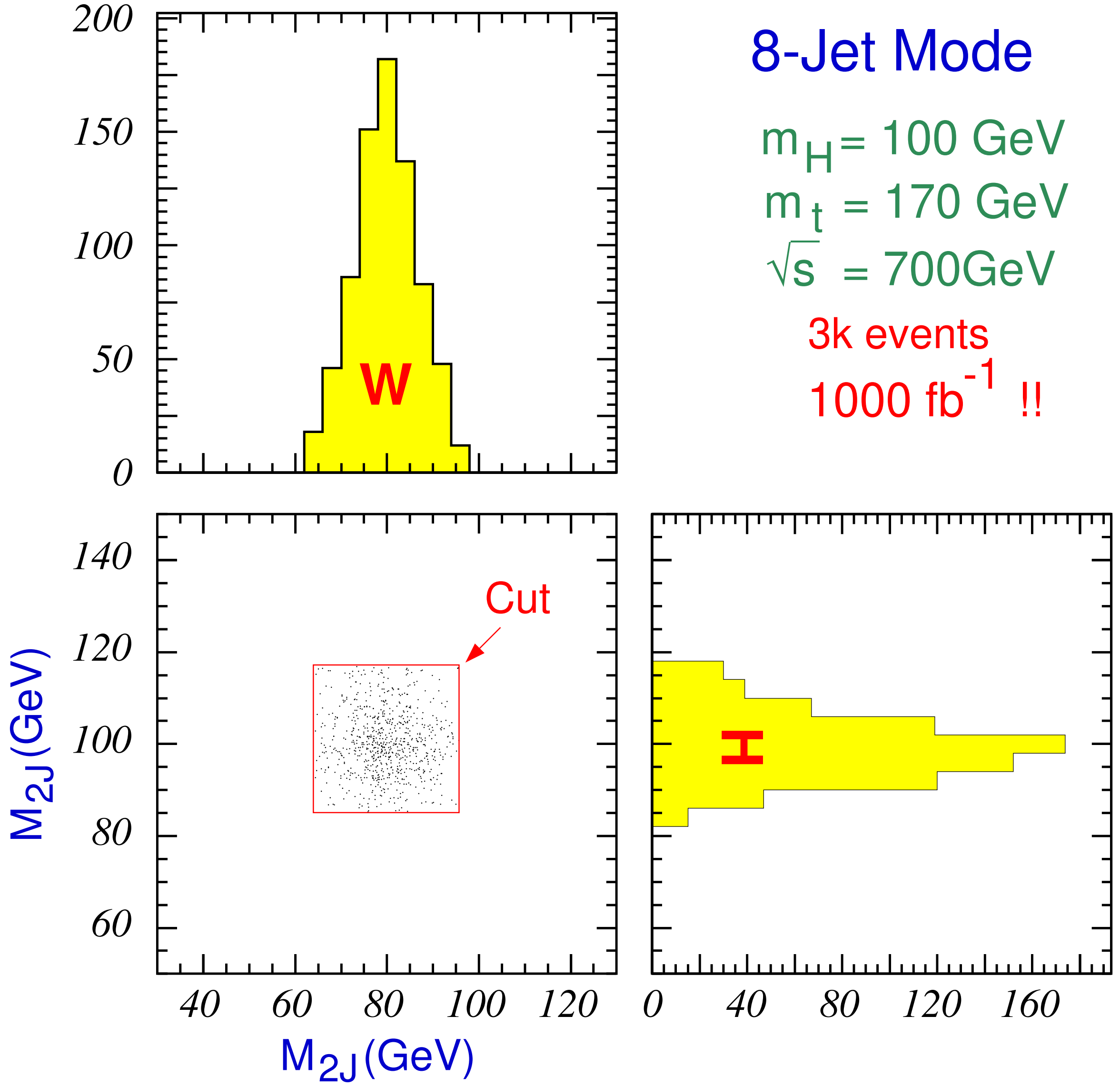
b-tagging

#b > 2 ------- JLC-I (Green Book) Values

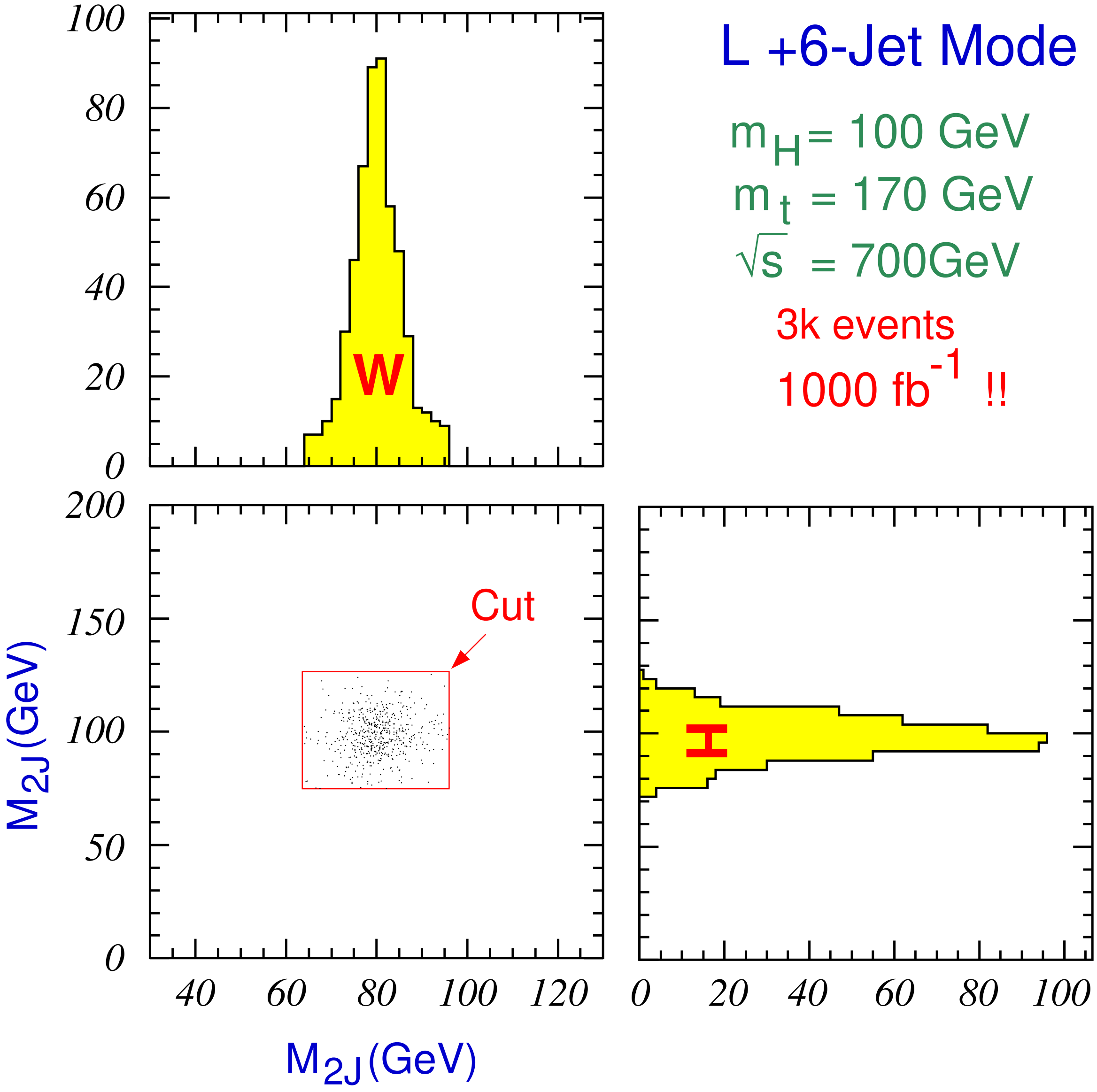
$\varepsilon_b = 0.78 \quad \varepsilon_c = 0.38$

S/B ratio strongly depends on m_H !

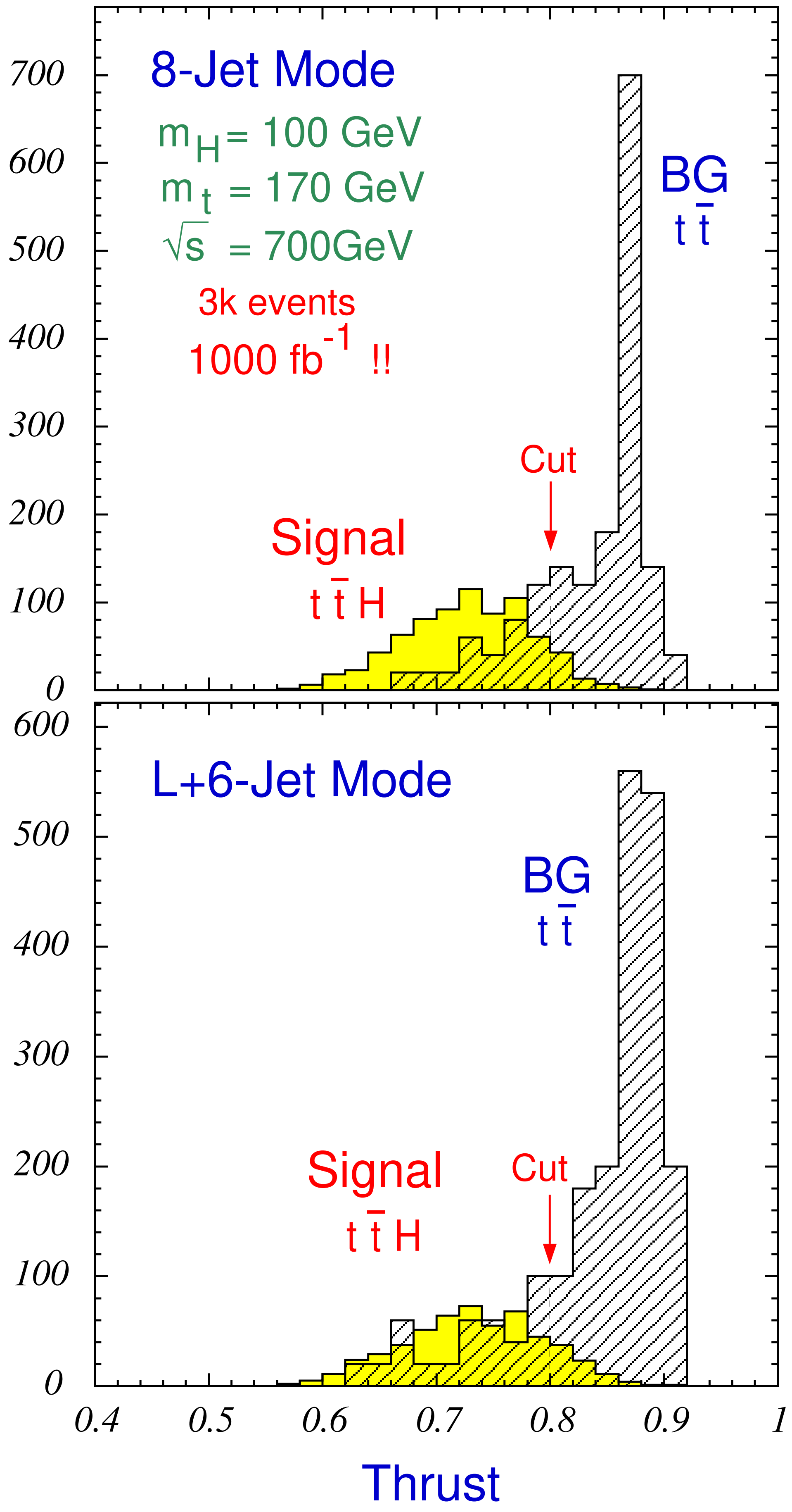
W/H ID via 2-Jet Invariant Mass



W/H ID via 2-Jet Invariant Mass



Reduction of Top Pair BG



Determination of Top Yukawa Coupling

Assume

$m_H = 100$ GeV $\quad m_t = 170$ GeV

$100\ \mathrm{fb}^{-1}$ at $\sqrt{s} = 700$GeV

and see if how well we can determine the top Yukawa coupling.

Signal

L+6 Jets or 8 Jets
with >2 b-taggs

$\sigma_{t\bar{t}H} \cong 3.0$ fb $\quad \epsilon_{t\bar{t}H} \cong (0.23 + 0.16) = 0.39$

BG

$\sigma_{t\bar{t}Z} \cong 4.2$ fb $\quad \epsilon_{t\bar{t}Z} \cong (0.088 + 0.048) = 0.14$

$\sigma_{t\bar{t}} \cong 402$ fb $\quad \epsilon_{t\bar{t}} \cong (0.0009 + 0.0010) = 0.0019$

with ISR + Beam Effects

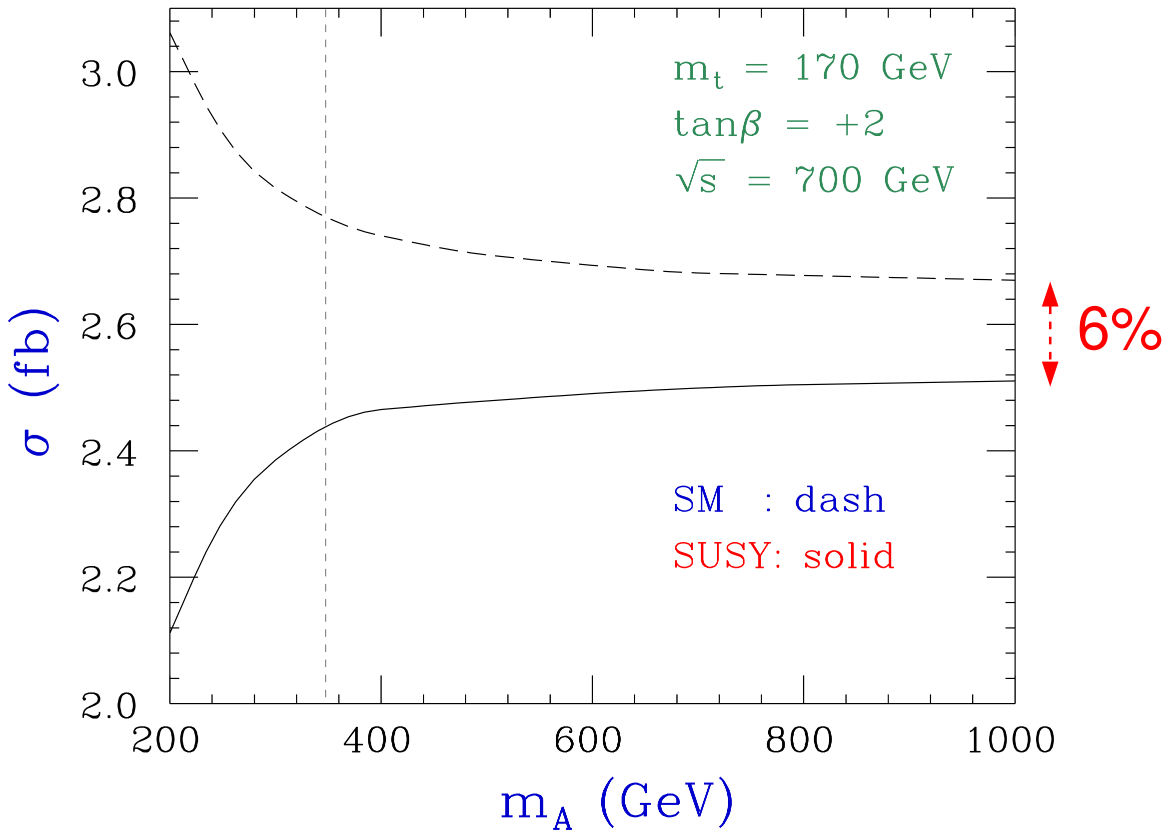
Sensitivity to Top Yukawa Coupling

$$\left\{\begin{array}{l} S = 114 \\ B = 133 \\ S/N \cong 0.86 \end{array}\right\} \xrightarrow{S(H) \propto \beta_H^2} \Delta\beta_H / \beta_H \cong 0.14$$

SM vs SUSY

Can we tell the difference?

Rather tough mission!



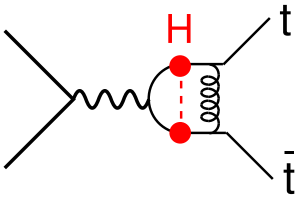
Notice that the Higgs mass changes with the pseudo-scalar mass !

Summary

Studied feasibility of top Yukawa measurements for

$m_H(100\text{GeV}) < 2\, m_t\,(170\text{GeV})$

Threshold Region



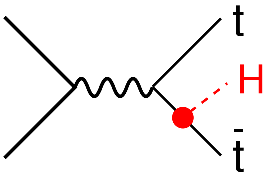
Precision luminosity measurement

Systematics limited

$\Delta\beta_H/\beta_H \cong 0.3$ 20 fb^{-1}

Higher Energy Region

$e^+e^- \rightarrow t\,\bar{t}\,H$



Good b-tagging to suppress BG

High Luminosity

Statistics limited

$\Delta\beta_H/\beta_H \cong 0.14$ 100 fb^{-1}