Measuring the top-Yukawa coupling at the 500 GeV ILC

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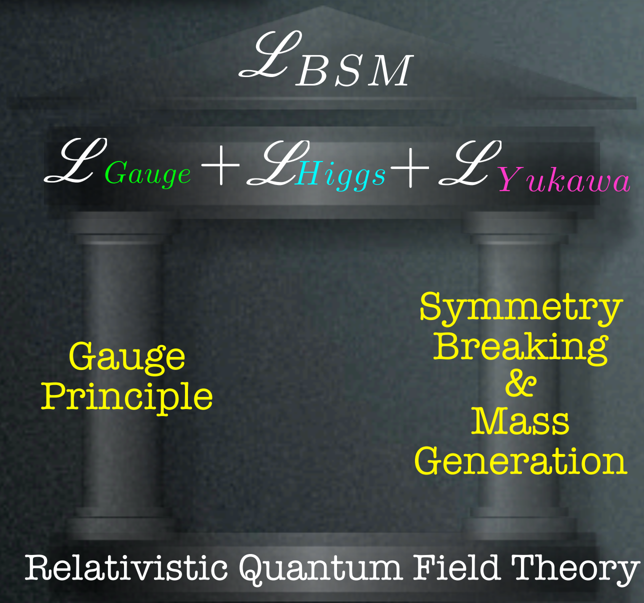


Two pillars of SM

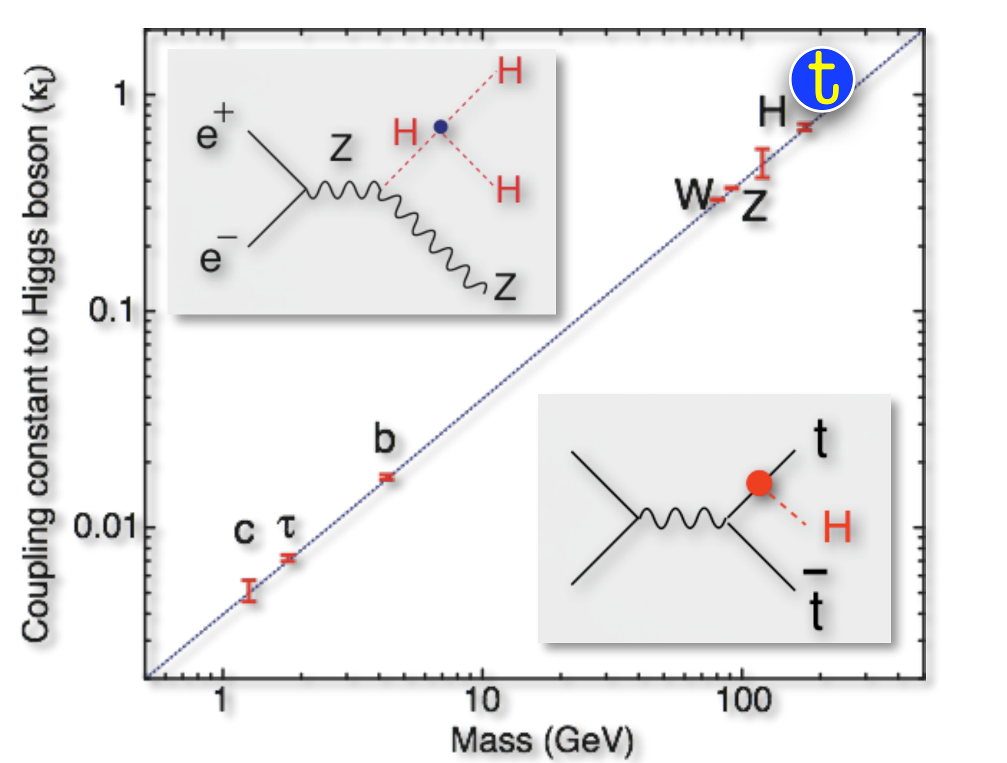
Standard model consists of two pillars:

- One pillar, gauge symmetry, has been established by precision EW studies.

- Another one, higgs mechanism, is still untested.

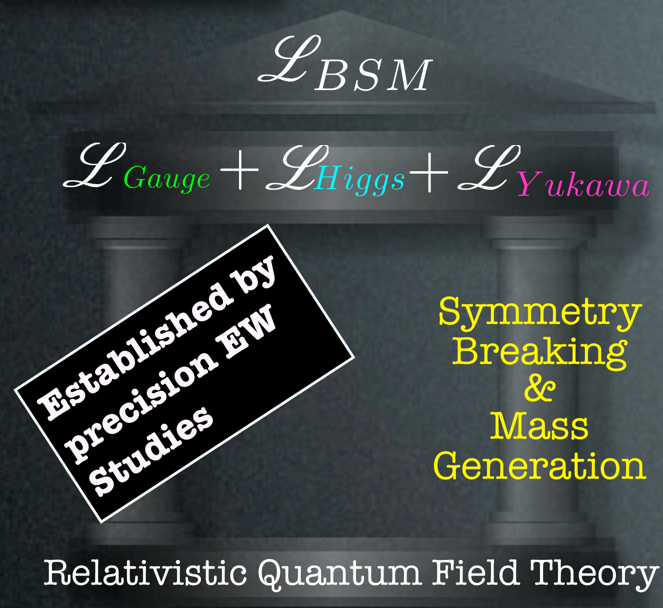
A critical mission for the ILC is the Higgs coupling measurement !

Relation between mass and coupling constant with Higgs



Higgs self coupling will be tested at ~**500 GeV** where e+e- -> ZHH cross section attains its maximum.

Our motivation is to confirm the untested pillar by measuring Top-Yukawa coupling at **500 GeV (1st stage of ILC)** concurrently to measuring Higgs self coupling.



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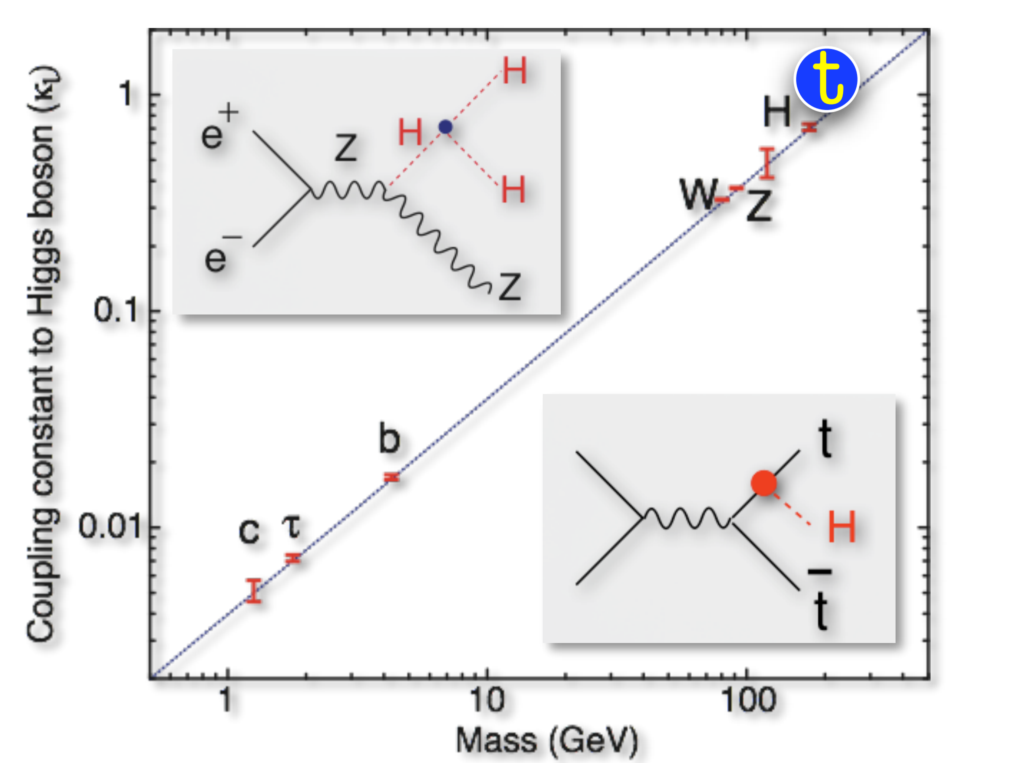

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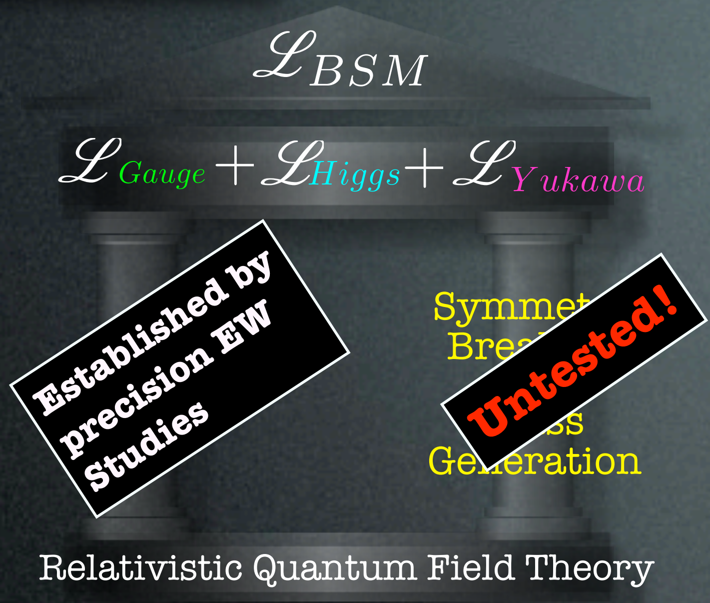

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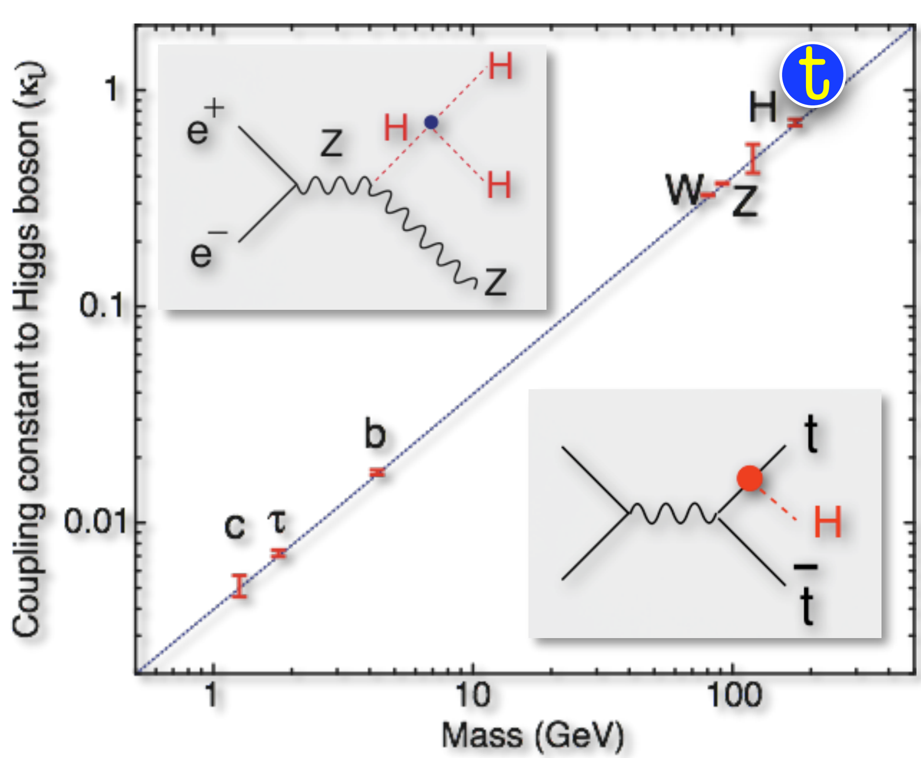

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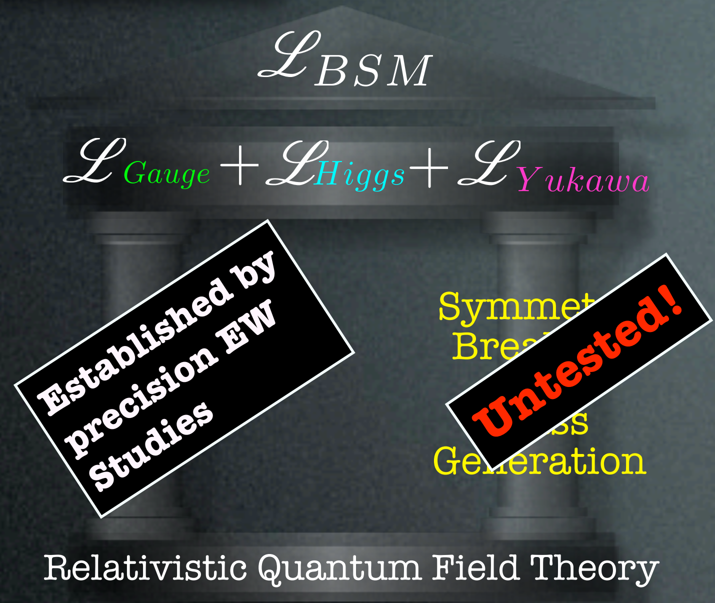

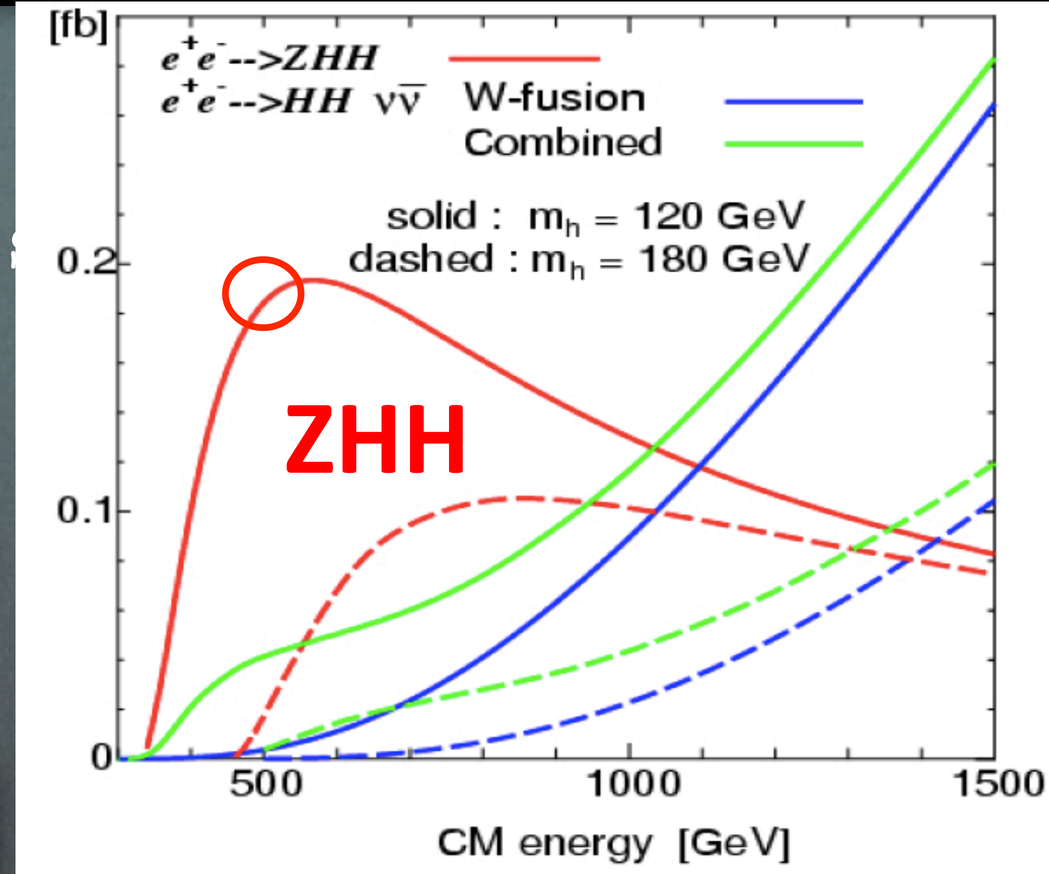

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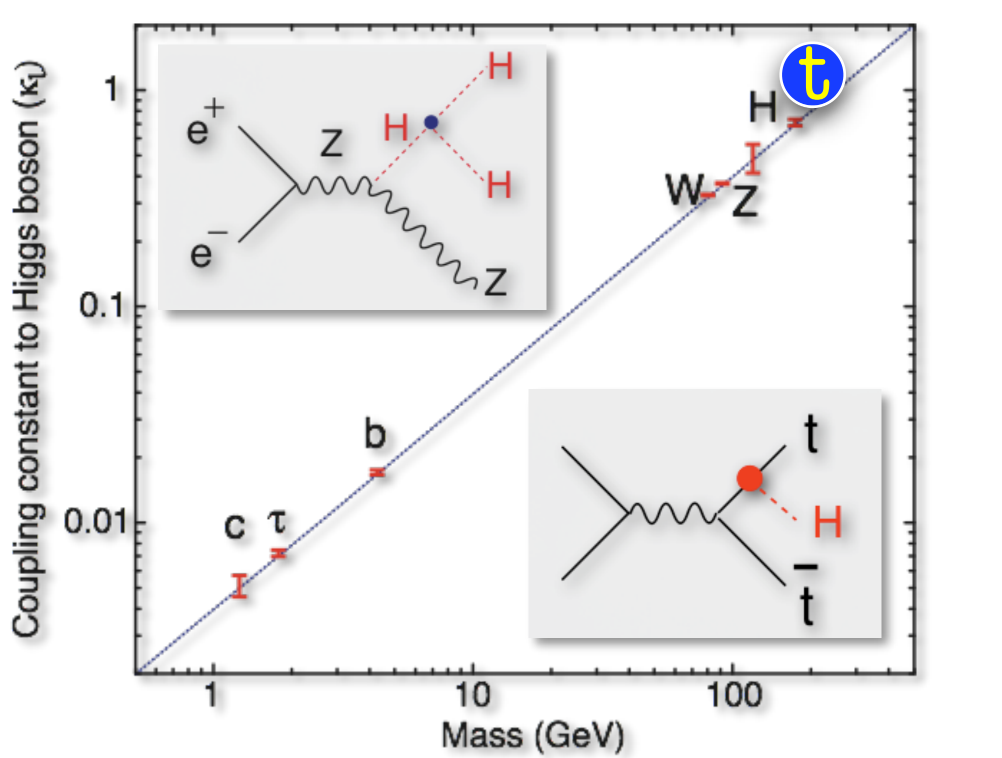

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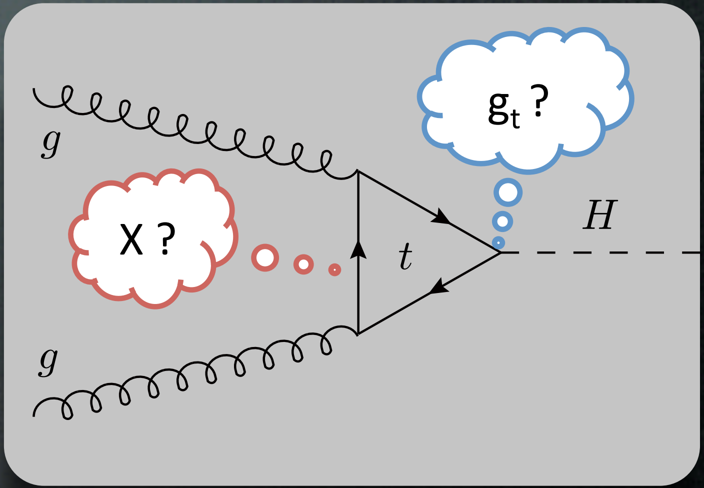
Top-Yukawa coupling < indirect measurement / direct measurement

- indirect measurement

The Higgs sector offers a broad range of possibilities for new physics ...

There is a possibility of a new particle X being in the loop.

It is difficult to distinguish X loop and top loop!

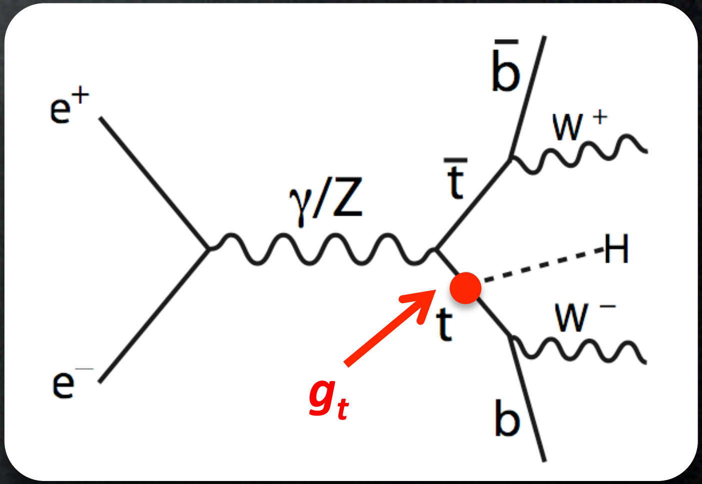


gg -> ttH @ LHC

- direct measurement

promising at ILC !!

main decay mode (H -> bb 68%) can be used



e+e- -> ttH @ ILC

Measurement of top-Yukawa coupling at 500 GeV

Past work estimated the measurement accuracy around E_{cm} = 700～800 GeV where the cross section reaches maximum.

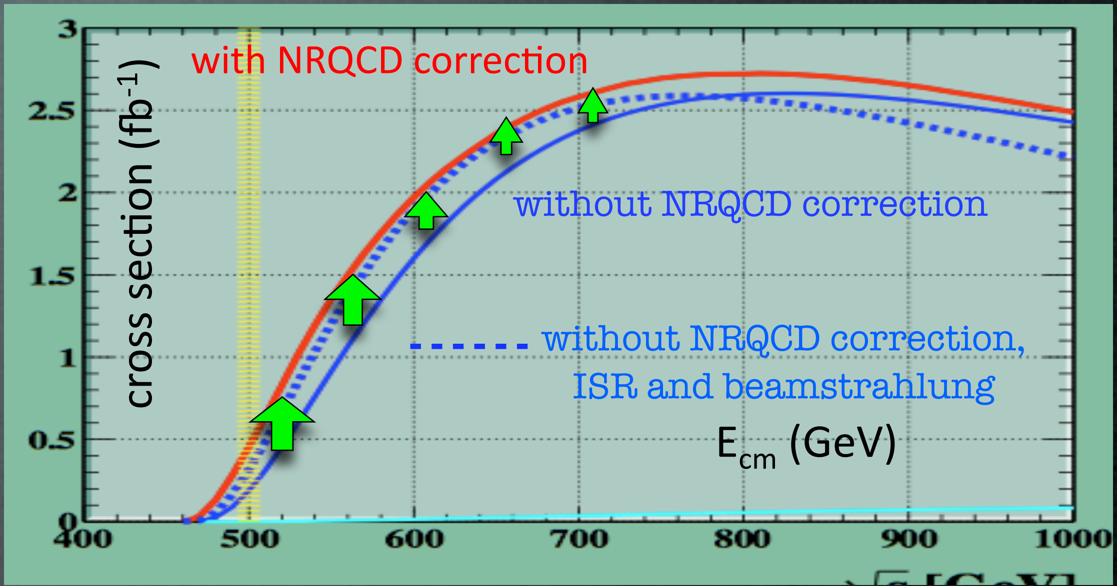
500 GeV is nearly threshold of ttH.

Cross section is smaller than 1 fb!

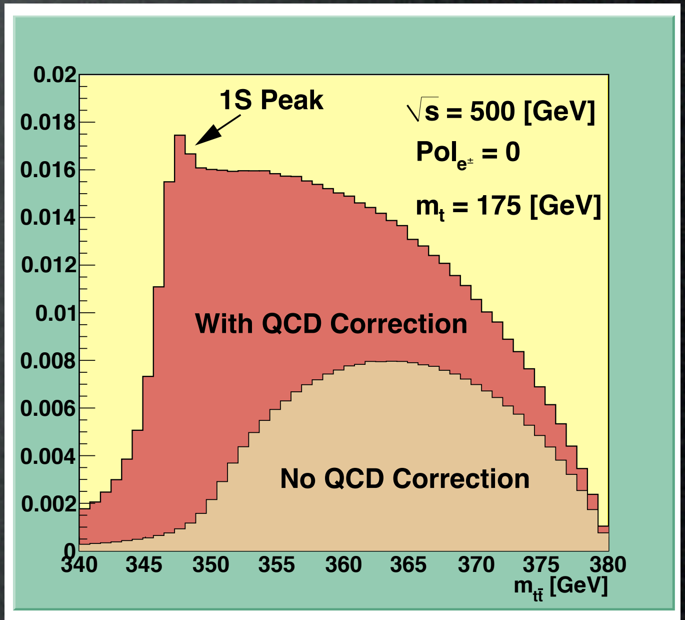
But ...

tt threshold correction enhances ttH production (and also ttZ)
(We assume M_{top} = 175 GeV in this study)

Cross section of ttH   enhancement



Invariant mass dist. for tt sysytem



This makes it possible to perform the direct g_t measurement at 500 GeV

Backgrounds

Main backgrounds

ttZ followed by Z -> bb (15%) same final state (t t Z -> bW bW bb)

→ irreducible background

tt threshold correction enhances σ_{ttz} from 0.7fb to 1.3fb

ttg* followed by g* -> bb same final state (t t g* -> bW bW bb)

→ irreducible background

tbW - huge cross section (~600fb)

- hard gluon emission from bottom quarks in tt process mimic signal (Since the tail of tt enters as background of ttH, it is important to include non-resonant contribution(tbW))
- even a tiny fraction of mis-reconstruction or b-tagging failure leads to significant background contamination.

The other possible backgrounds ?

W*W*/Z*Z -> ttbb small contribution (< 0.01fb)

qq (5 flavors), WW, ZZ, ZH have different signature from ttH signal.

- can be separated with 4×b tagging, event shape cut and mass cut

We generated signal(ttH) and main backgrounds (ttZ, ttg*, tbW).

Basic idea to reduce backgrounds

backgrounds	tbW	ttZ	ttg*
event shape compared to ttH	Effective ! different	same	same
maximum number of b-jets	2	4	4
Higgs candidate(Z, g*) mass compared to H	none	Effective ! different	Effective ! different

Analysis Framework

- Event generator : physsim
  - full helicity amplitude calculation by HELAS
  - MC phase space integration by BASES/SPRING

  ISR & beamstrahlung are included

  NRQCD correction for ttH and ttZ is included

  Dedicated ttg generator with correct color strings

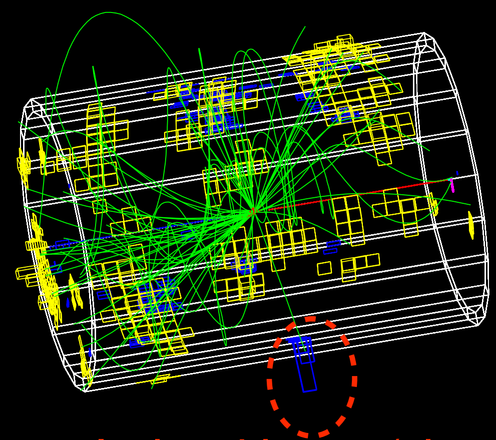
- Parton shower & hadronization: pythia

- Fast detector simulation: JSF

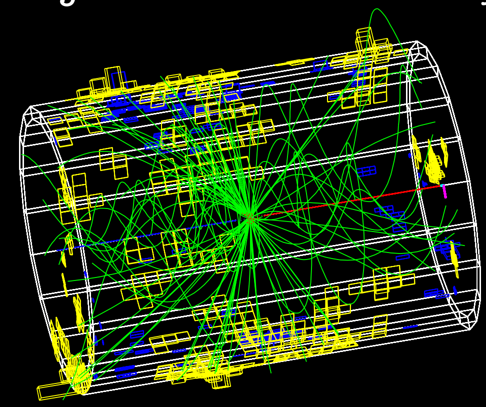
Detector parameters

Detector	Performance	Coverage
Vertex detector	$\sigma_b = 7.0 \oplus (20.0/p)/\sin^{3/2}\theta \mu m$	$\lvert\cos\theta\rvert \leq 0.90$
Central drift chamber	$\sigma_{P_T}/P_T = 1.1 \times 10^{-4} p_T \oplus 0.1\%$	$\lvert\cos\theta\rvert \leq 0.95$
EM calorimeter	$\sigma_E/E = 15\%/\sqrt{E} \oplus 1\%$	$\lvert\cos\theta\rvert \leq 0.90$
Hadron calorimeter	$\sigma_E/E = 40\%/\sqrt{E} \oplus 2\%$	$\lvert\cos\theta\rvert \leq 0.90$

ttH L+6-jet mode event display



ttH 8-jet mode event display



Charged particle tracks

Signals on H-Cal.

Signals on E-Cal.

Cut values

There is room for improvement !

6-Jet + lepton	8-Jet
# of isolated lepton = 1	# of isolated lepton = 0
$Y_{5\text{->}4}$ = 0.01	$Y_{8\text{->}7}$ = 0.00080
thrust > 0.86	thrust > 0.7
b-tagging (at least 4 b-jet)	b-tagging (at least 4 b-jet)
140 GeV < top mass < 205 GeV	136 GeV < top mass < 211 GeV
90 GeV < higgs mass < 150 GeV	77 GeV < higgs mass < 149 GeV

Very preliminary !

Cut flow (**6Jet + lepton**, lumi. = 1 ab^{-1}, unpolarized beams)

Very preliminary !

Cut	ttH(6J+L)	ttH (8J, 4J+2L)	tbW(inc. tt)	ttZ	ttg* (g* -> bb)	significance
no cut	167	212	583718	1340	697	0.22
Single isolated lepton	106	28.6	203806	441	242	0.23
thrust < 0.86	105	27.5	171238	426	229	0.25
$Y_{5\to4} > 0.01$	55.1	10.3	2368	152	33.0	1.1
4×b-tagging	22.3	1.6	33.1	20.7	11.6	2.4
mass cut	19.2	0.7	10.2	16.4	6.0	2.6

H -> bb (68%) Z->bb (15%)

Cut flow (8Jet, lumi. = 1 ab^{-1}, unpolarized beams)

Cut	ttH(8J)	ttH (6J+L, 4J+2L)	tbW(inc. tt)	ttZ	ttg* (g^* -> bb)	significance
no cut	172	207	583718	1340	697	0.22
Isolated lepton veto	158	54.3	349054	752	418	0.27
thrust < 0.8	99.2	27.4	62317	454	184	0.39
$Y_{8\to7}$ > 0.00082	72.4	8.9	3029	214	48.5	1.25
4×b-tagging	42.6	4.6	144.2	45.0	28.8	2.62
mass cut	34.7	0.5	33.8	31.0	12.4	3.27

H -> bb (68%) Z->bb (15%)

Result summary

1 ab^{-1}

Beam pol. (e- , e+)	6Jet+lepton		8Jet	
	S / N	significance	S / N	significance
(0 , 0)	19.2 / 33.3	2.6	34.7 / 77.7	3.3
(-0.8 , +0.3)	32.4 / 56.8	3.4	58.4/ 128.1	4.3

Very preliminary !

Combined results

1 ab^{-1}

Beam pol. (e- , e+)	Combined significance	Combined $\Delta g_t/g_t$
(0, 0)	4.2	11.9%
(-0.8, +0.3)	5.5	9.1%

(stat. error only)

Summary & Plan

We assumed early stage ILC

- E_{cm} = 500 GeV
- luminosity 1 ab^{-1}
- polarized beams (-0.8, +0.3)

Fast simulation studies suggests
~**10%** accuracy on top-Yukawa coupling is achievable.

We will move on to full simulation studies.

The analysis will be also performed at E_{CM} = 1 TeV as part of the DBD benchmark studies.