Summary of the Top/QCD Working Group

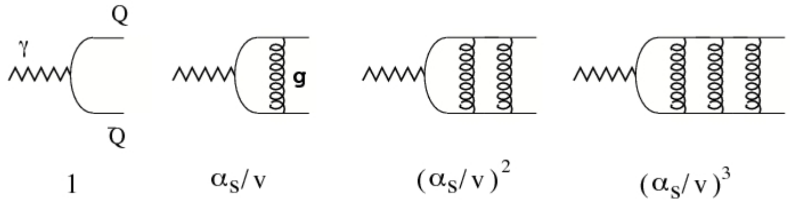
Conveners: Stewart Boogert, Phil Burrows, Juan Fuster, Andre Hoang, Thomas Teubner

Top/QCD program

Contribution List | Time Table

id	date	dur.	type	title	presenters
96	2006-Nov-08 09:00	20'		Two-loop Bhabha scattering and luminosity determination at e+e- colliders	Dr. PENIN, Alexander
97	2006-Nov-08 09:20	20'		Dimension-six top-Higgs interaction and its effect in collider phenomenology	Dr. TSUMURA, Koji
98	2006-Nov-08 09:40	20'		Complete Higgs mass dependence of ttbar threshold production to order alpha alpha_s	STEINHAUSER, Matthias
99	2006-Nov-08 10:00	20'		New results for massive coloured pair production	Dr. RUIZ FEMENIA, Pedro
100	2006-Nov-08 10:20	20'		alpha_s at Giga-Z	WINTER, Marc
103	2006-Nov-08 11:15	20'		Fermionic corrections to the matching coefficient of the vector current	PICLUM, Jan
104	2006-Nov-08 11:35	20'		NLL ultrasoft running of QCD potentials	STAHLHOFEN, Maximilian
105	2006-Nov-08 11:55	20'		Top-antitop production near threshold with pNRQCD	PINEDA RUIZ, Antonio
106	2006-Nov-08 12:15	20'		Accelerator parameter impact on the top threshold mass	Dr. BOOGERT, Stewart

$t\bar{t}$ at threshold



- ⋆ We want m_t with better than per mille accuracy — Heinemeyer et al.

  $\longrightarrow$ EWSB (indirect m_H det.), SUSY parameters, low energy...GUT connection

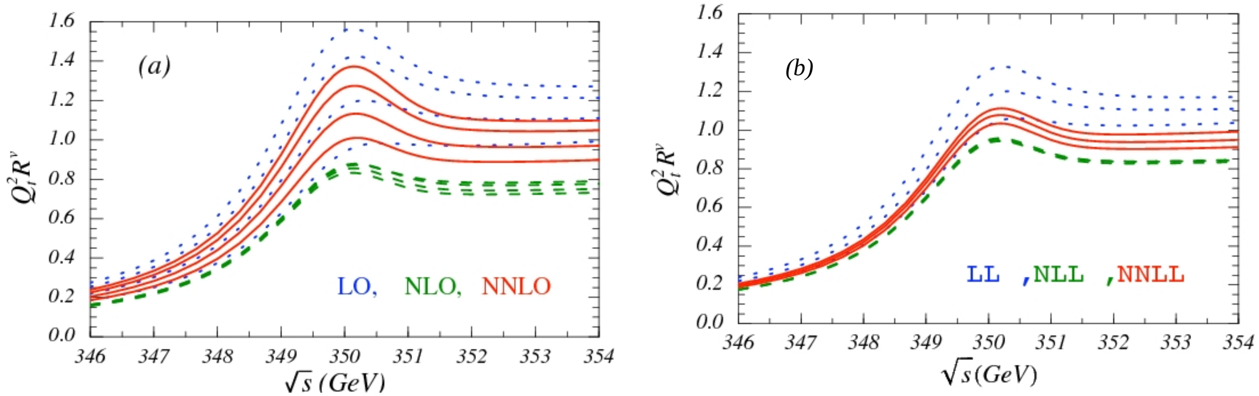
- ⋆ Threshold scan $e^+e^- \longrightarrow t\bar{t}$ the only known way to achieve $\Delta m_t < \Lambda_{\rm QCD}$

  $\longrightarrow$ *counting* $bW^+\bar{b}W^-$ colour singlett states

- ⋆ Threshold dynamics understood at NNLL and N^{3}LO (nearly complete) (Steinhauser et al.)

  $\longrightarrow$ *Effective Field Theories* (v,p)NRQCD; $1S$ (or PS) mass scheme, *not pole mass*

$\sigma(e^+e^- \longrightarrow t\bar{t})$, $1S$ scheme in a) 'fixed order', b) RG-improved: (Hoang+Manohar+Stewart+T)



Higher Order EW + QCD

current status for normalization uncertainties $\delta\sigma_{\rm tot}/\sigma_{\rm tot}$:

- fixed-order approach: NNLO (✓), NNNLO (partial) $\longrightarrow \sim 20\%$
- renormalization-group improved: NLL$_{\rm QCD}$ (✓), NNLL (partial) $\longrightarrow \sim 6\%$

aims of the workshop participants:

- FO approach: full NNNLO$_{\rm QCD+EW+lifetime}$
- RGI approach: full NNLL$_{\rm QCD+EW+lifetime}$

$\longleftarrow$ exp. req.: $\leq 3\%$

- Monte Carlo for simulations — Boogert, Gounaris

contributions at Valencia:

$\longrightarrow$ analysis on known NNLL$_{\rm QCD}$ corrections in pNRQCD — Pineda

$\longrightarrow$ new results on ultrasoft log summation (NNLL$_{\rm QCD}$) in vNRQCD — Stahlhofen

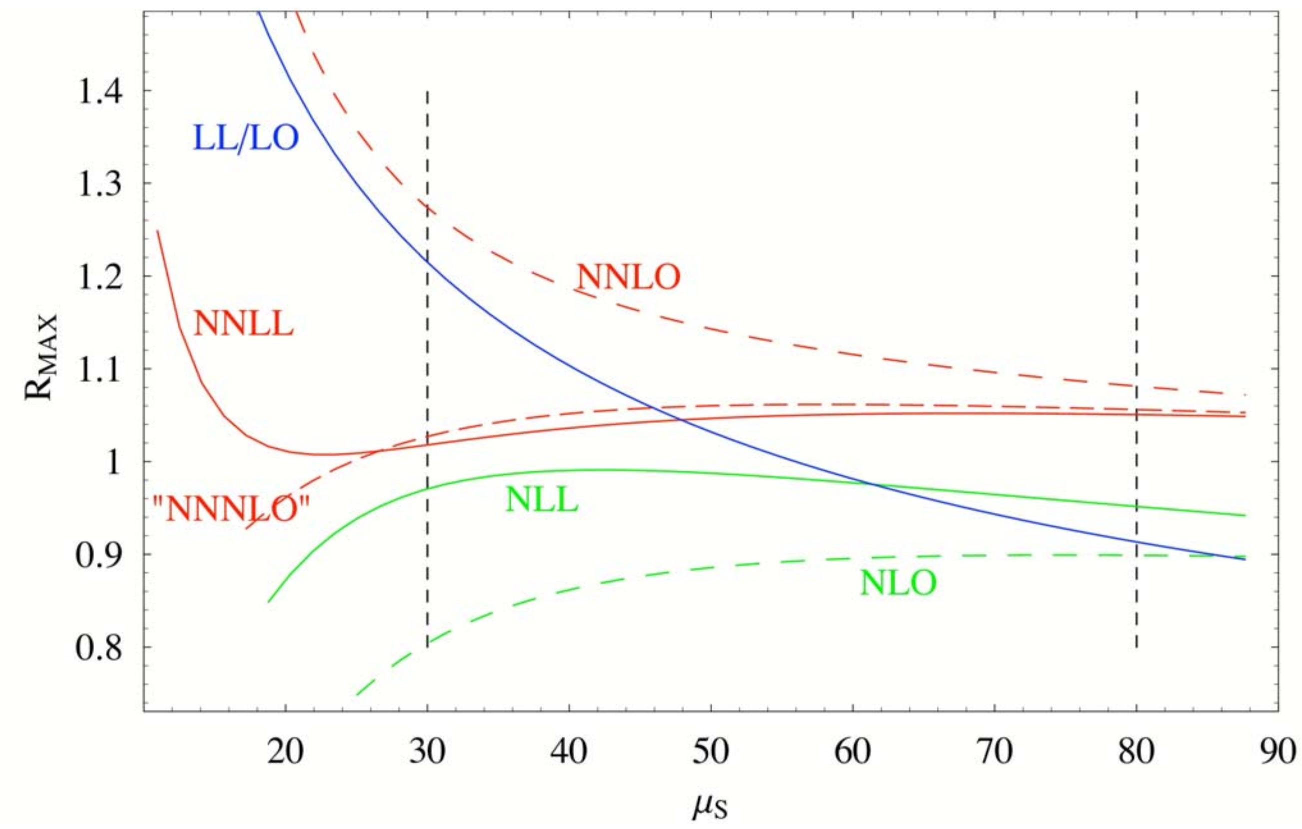
$\longrightarrow$ $\mathcal{O}(\alpha_s)$ corrections to virtual Higgs exchange (NNNLO$_{\rm EW}$) — Steinhauser

$\longrightarrow$ light quark n_f corrections to effective $t\bar{t}$ current (NNNLO$_{\rm QCD}$) — Piclum

$\longrightarrow$ effects of finite top lifetime (NNLL$_{\rm lifetime}$)
theory set-up for squark-antisquark pair threshold — Ruiz-Femenia

$\Longrightarrow$ lot's of ongoing work, much more work needed.

Fixed order vs resummed



- Normalization (and peak position) stabilised by higher orders;
  - summation of leading logs important
  - N^3LO improves NNLO considerably

Instability Effects

observable final state: $e^+e^- \to W^+W^-b\bar{b}$

"inclusive" treatment

Ruiz-Femenia

⇒ Optical Theory: effective complex indices of refraction for absorptive processes

⇒ NRQCD: contributions from real Wb final states included in EFT matching conditions to QCD+ew. theory (=SM)

- complex Wilson coefficients & RGE's
- effective Lagrangian non-Hermitian
- total rates through the optical theorem
- phase space matching: $\sigma_{tot} = \sigma_{\rm tot}$(experimental cuts)
- interference: e.g. $\mathcal{M}(e^+e^- \to t\bar{t} \to WWbb) \leftrightarrow \mathcal{M}(e^+e^- \to WWbb)$

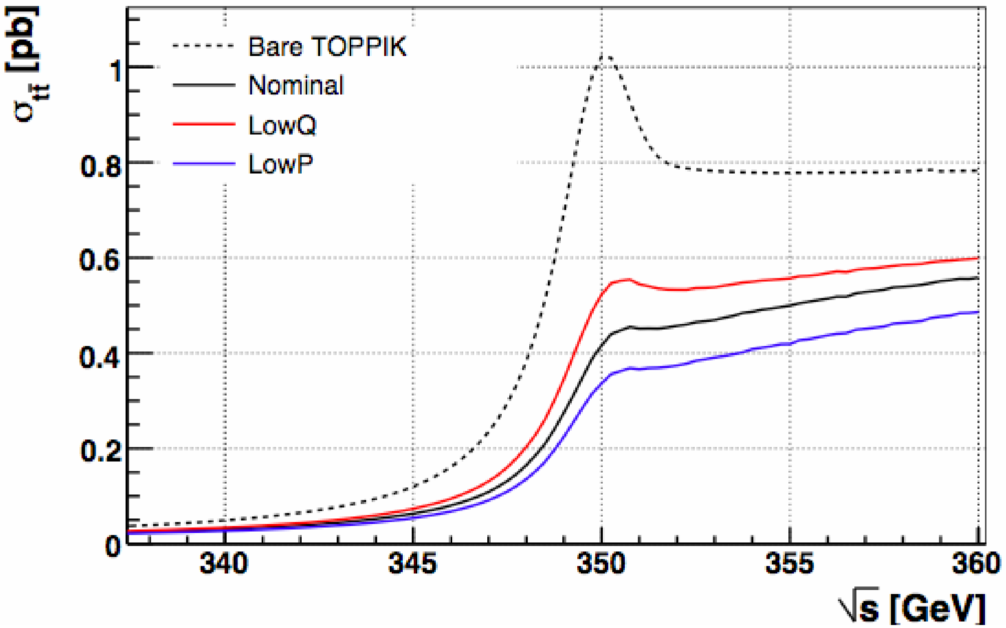
Threshold top quark production

Boogert, Gournaris

- Experimental threshold complicated by beam effects
  - Luminosity spectrum $\frac{dL}{d\sqrt{s}}$
  - Absolute beam energy $\langle\sqrt{s}\rangle$

$$\sigma_{obs}\left(\sqrt{s}\right)=\frac{1}{L_0}\int_0^1 L(x)\sigma\left(x\sqrt{s}\right)dx$$

- Machine parameters (interaction point beam sizes) change beamstrahlung component of luminosity spectrum
- Increase beamstrahlung reduces effective luminosity at threshold
  - Small modification to shape



ILC accelerator parameters

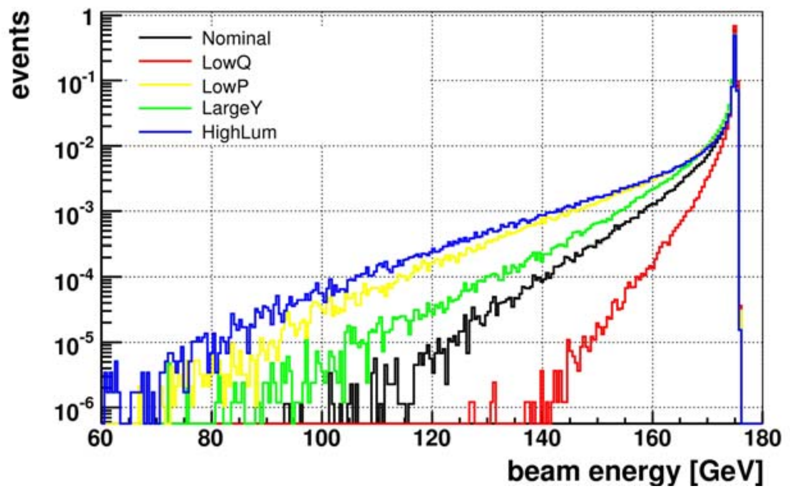
Boogert, Gournaris

- Parameter group question

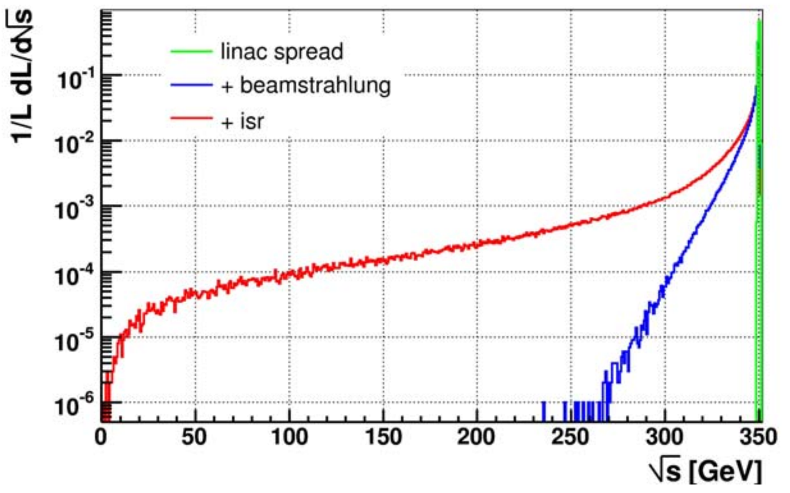
  Is there any impact of decreasing (increasing) beamstrahlung by a factor of two relative to the standard parameters?

- Simulated 5 possible scenarios

  Low-Q, Nominal, Large-Y, Low-P, High-L
- Simulated using Guinea-Pig
  - Fitted using CIRCE-like parameterization



- Total luminosity spectrum also includes
  - Intrinsic energy spread
  - Initial state radiation



- Bhabha acolinearity
  - Theoretical developments
    - New 2 loop calculations
    - Monte Carlo generators
  - Beamstrahlung extraction
    - Statistical error small
    - Systematic errors being evaluated

Projected total top mass error

Boogert, Gournaris

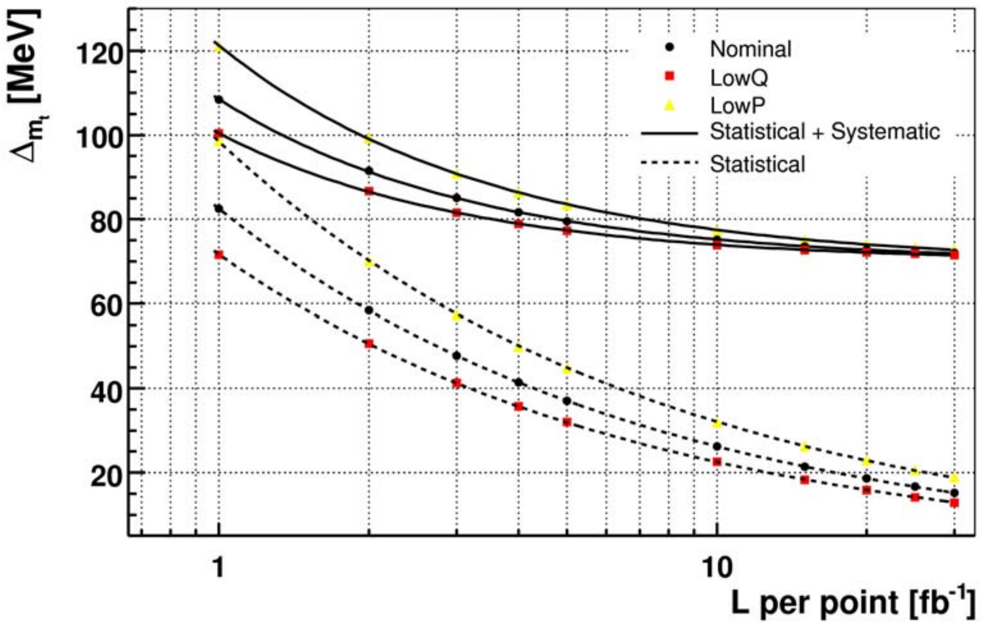
- Statistical error
  - Obtained directly from threshold fit

    Δm_t(stat-fit) = 100 to 15 MeV
  - Depends on parameter set
- Theory error (estimate)
  - From theoretical uncertainty in threshold cross section

    Δm_t(theory) = 35 MeV
- Absolute beam energy scale
  - Assumed precision of beam energy diagnostics 1 part in 10^4

    Δm_t(e-beam) = 35 MeV
- Luminosity spectrum
  - Beamstrahlung component can be well measured
  - K. Mönig & S. Boogert
  - Systematic error studies ongoing

    Δm_t(spectrum) = 2 MeV and 70 MeV

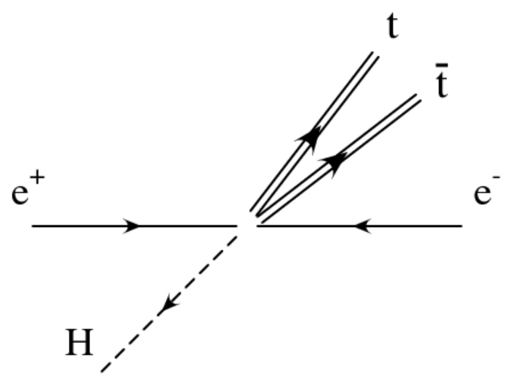


Top-Yukawa coupling y_t from $t\bar{t}H$

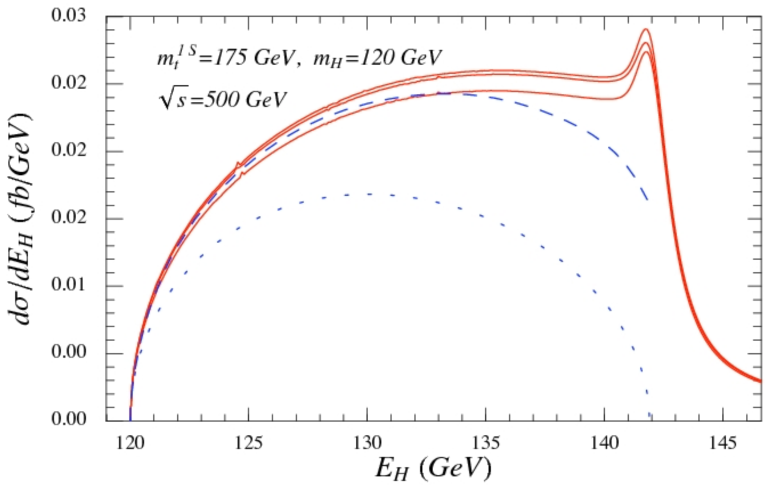
- Aim: measure top Yukawa coupling via $\sigma(e^+e^- \to t\bar{t}H) \sim g^2_{ttH}$ at ILC.
- Challenging due to complicated final state, low rates, backgrounds,...
- Earlier analysis:
  - ILC (800 GeV, 1000 fb^{-1}): $\Delta g_{ttH}/g_{ttH} \sim 6(10)\%$ for $m_H = 120(190)$ GeV
  - estimate for baseline (500 GeV, 1000 fb^{-1}): $\Delta g_{ttH}/g_{ttH} \sim 24\%$ ($m_H = 120$ GeV)
- But: QCD helps!

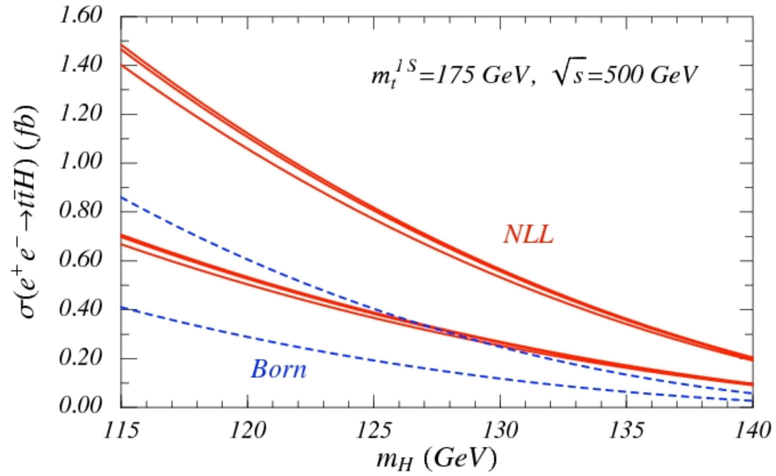
$\star$ At $\sqrt{s} \sim 500$ GeV, $t\bar{t}H$ is non-relativistic and dominated by threshold dynamics

$\rightsquigarrow$ large enhancement, calculable in NRQCD



Calculations by Farrell+Hoang for $t\bar{t}H$ at NLL in vNRQCD:





lower lines: $(P_+, P_-) = (0, 0)$, upper lines: $(P_+, P_-) = (+0.6, -0.8)$

- Choice of (e^+ and e^-) polarization is crucial

▶ First estimates from Aurelio Juste:

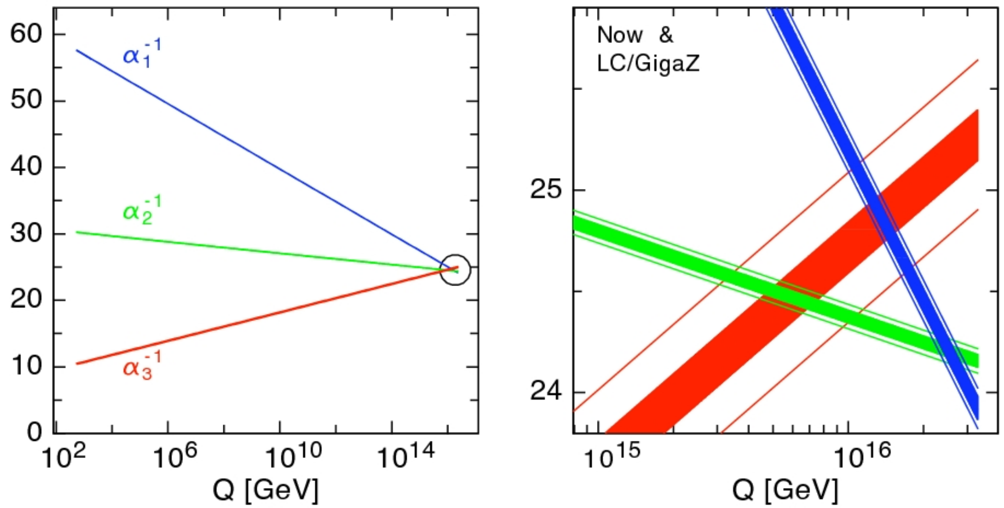
  – Enhancement of σ_{tth} from QCD for $m_H = 120$ GeV : $\times 2.4$

  – From use of beam polarization: $\times 2.1$

  ⇝ Anticipate $\boldsymbol{\Delta g_{ttH}/g_{ttH} \sim 10\%}$ for baseline ILC, $m_H = 120$ GeV.

α_s at the percent level

- High precision α_s determination is crucial for accurate predictions of many signal and background processes, e.g. as input in the $t\bar{t}$ analysis.
- The current precision of α_s is not sufficient.
- α_s is the least precise input for coupling unification in SUSY, GUT's:



- With Giga$Z$ α_s could be improved significantly:

α_s with Giga$Z$

- Vastly increased statistics + better detector performance than LEP1
  $\rightsquigarrow$ Z line-shape observables with much better precision
- From $\sigma(e^+e^- \rightarrow hadrons)$ and $\sigma(e^+e^- \rightarrow l^+l^-)$ on Z pole:
  $R = \sigma_{had}/\sigma_{lept}$, Γ_Z, σ^0_{had}, $\sigma^0_{lept} = 12\pi\Gamma^2_{lept}/M^2_Z\Gamma^2_Z$
- depend on α_s, computable in perturbative QCD with very high precision and best systematic uncertainties:
  - fully inclusive process
  - three loop, partial 4-loop — Chetyrkin+Kühn et al.
  - proper treatment of off-shell effects needed
- Combining the four variables (R is dominating), the estimated absolute accuracy for α_s at Giga$Z$ is extremely high,

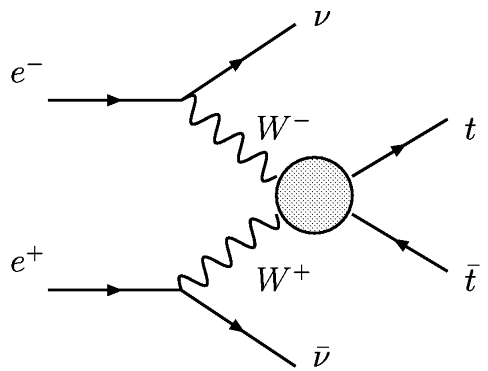
$$\Delta\alpha_s(M_Z) = 0.0005 - 0.0007$$

Dimension 6 top-Higgs coupling

Koji Tsumura

– We discuss the W-fusion with the non-SM Y_t which are characterized by dim.6 operators.

$$y_t^{\text{eff}}(-q^2,\Lambda) = y_t^{\text{SM}} - v^2\frac{C_{t1}}{\Lambda^2} - q^2\frac{C_{Dt}}{2\Lambda^2}$$



– They are constrained by experimental data and unitarity.
  - Our calculations have been checked by ET.
  - The W-fusion has been analyzed by EWA and CalcHEP.

Conclusion

- Dim.6 couplings can enhance $\sigma(e^-e^+ \to W^-W^+\nu\bar{\nu} \to t\bar{t}\nu\bar{\nu})$

.

At the ILC with $\sqrt{s} = 500\text{GeV},\ \text{and}\ \int \mathcal{L}dt = 500\text{fb}^{-1}$, several hundred events are expected. Statistical error is less than 10 %. Therefore the effect of dim.6 couplings can be observed.

Future directions

- Experimental analyses for $t\bar{t}H$ at ≤ 500 GeV
- MC for the $t\bar{t}$ threshold; optimized scan strategy
- new physics effects for the $t\bar{t}$ threshold
- Top in the continuum: mass reconstruction;
  (anomalous) couplings, dedicated systematics studies
- (heavy) jet analyses
- ...